# HANDBOOK OF ANÆSTHETICS

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BY

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# PREFACE TO THE FOURTH EDITION

In assuming sole responsibility for the production of this edition I should state at the outset that it is built on Dr Ross's original book. As will readily be seen, much of his valuable groundwork remains. It could not be improved upon. Mr Wood has again kindly revised the chapter on Local Anæsthesia.

Otherwise the book has been brought up to date by the *inclusion of new methods and new apparatus* which seem to have established a definite claim to recognition.

H P FAIRLIE

*February* 1935

# PREFACE TO THE THIRD EDITION

THE name of Dr Fairlie, which appears with my own on the title page of this edition, is too well known to require much introduction from me He has written extensively upon anæsthesia, and has much experience in the teaching of the student Much of the work of revision and of the preparation of new material has fallen upon his shoulders, but we are jointly responsible for the whole book, with the exception of the chapters upon Local and Spinal Analgesia, which Mr Wood contributed to the first edition, and which he has once more been good enough to revise for the present one

We have used the pruning knife freely, particularly in the section devoted to gas oxygen, where extended experience has enabled us to concentrate upon two instruments to the exclusion of several others now of greater interest to the historian than the student of medicine

Ethylene and oxygen bids fair to secure a definite place in the field of anæsthesia, and Dr Fairlie's experience of this new agent has enabled him to write the new chapter upon it, appearing for the first time in the present edition

The rest of the book has been fully revised in the light of modern work, but throughout we have adhered to the

idea which underlay the first edition, which was to lay all the emphasis upon first principles and to teach the student to think things out for himself

J S ROSS

*January 1929*

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# Handbook of Anæsthetics

## CHAPTER I

### ABSORPTION AND PHYSIOLOGICAL ACTION OF ANÆSTHETIC DRUGS

THE full action of any drug will not be manifest until it is absorbed into the tissues of the system we are seeking to influence. In the case of inhalational anæsthetics we have, then, to consider how a vaporised drug such as ether or chloroform brought into the neighbourhood of the patient's mouth is transferred to his brain. We shall find that each step of this transfer takes appreciable time.

The first stage is from inspired air to air of the lung alveoli. For its due completion, free performance of the natural act of external respiration is necessary. The air inspired by the patient will contain a certain proportion of the vaporised drug, but it must be remembered that the volume of that inspiration is only about a fifth of the total volume of air contained in the lungs and air passages. By the time that the normal process of diffusion has carried the anæsthetic into the lung alveoli, considerable dilution of its strength will therefore have taken place, and it will only be after a considerable number of inspirations that the strength of the anæsthetic vapour in the alveoli will approximate to that in the inspired air.

The process of absorption of the anæsthetic vapour from the air of the lung alveoli into the blood is mechanical,

not physiological It depends upon the physical laws which govern the diffusions of gases through a membrane, a process which the student will remember proceeds until the partial pressure of the gas on each side of the membrane is equal In the case of such vapours as ether and chloroform the process takes an appreciable time, for the pressure on the one side of the membrane is not so very much higher than that on the other side * We habitually shorten the period by using during the induction period, as high a strength of the vapour as we can do with safety and comfort to the patient, but when the requisite saturation of the blood is believed to have been effected, we *gradually* lower the strength of vapour in the level which will maintain equipoise The reason why this lowering of vapour strength in the atmosphere administered to the patient must be gradual is that the saturation of the tissues (especially the nerve tissues) with anæsthetic withdrawn from the blood stream, is slow—slower than that of the blood from the lung air During the early part of an administration the blood is constantly drained as it were of anæsthetic by the tissues, and if we reduce too rapidly the strength of vapour being administered to the patient, he begins to come out '

Reaching the blood stream then, by absorption from the lung alveoli, the drug enters into loose combination with the red blood corpuscles, a small part only is carried by the plasma Within the corpuscles it displaces a certain amount of the oxygen normally carried, this point is of great importance only in the case of nitrous oxide gas which displaces the larger part of the oxygen content of the corpuscles In the case of other anæsthetics, the

* Nitrous oxide being given undiluted with air its partial pressure in the lung alveoli rapidly becomes very high This anæsthetic is therefore absorbed very rapidly

same process occurs, but to a less extent Detailed figures showing the alteration in the composition of the blood gases in the various stages of chloroform anæsthesia will be found in Appendix III

The actions of individual drugs upon the circulatory, respiratory, and excretory systems differ so considerably that a small section has been devoted to this subject in each of the chapters devoted to nitrous oxide, ether, and chloroform respectively One feature is, however, dependent upon the *state of anæsthesia* rather than the action of the particular drug, and that is a certain slight fall of blood pressure This phenomenon is seen even in natural sleep, and is presumably due simply to lack of normal stimuli, such as tactile, visual, and auditory impressions which in the ordinary circumstances of life help to maintain the tone of the vasomotor system That such a fall is due to the *state* of anæsthesia admits of little doubt, but the fact is not always easy to demonstrate since each of the drugs themselves has a marked influence upon the B P, which masks the pure effect of the anæsthetic sleep

## ACTION UPON THE NERVOUS SYSTEM

It is in this system, of course that we look for the characteristic action of anæsthetics It used to be said that anæsthetics paralyse the brain from above downwards, but that is only approximately true More correctly we may say that the more highly developed parts of the brain are earliest affected, and that those portions, such as the vital medullary centres, which man shares in common with his humbler zoological relatives, maintain their activity until the last Moreover, it must be remembered that before any brain centre succumbs, it passes through a preliminary stage of *excitement*, varying in intensity with

varying drugs and also with different types of patients Those who are accustomed to administer to their nervous centres repeated large doses of such nerve poisons as alcohol and tobacco, may show very evident signs of this preliminary cerebral irritation during the process of induction of anæsthesia, so do also the unhappy possessors of nervous systems deranged from other causes, such as epilepsy

*The first centres to be attacked are those of thought and perception* The patient is incapable of coherent reasoning, and loses touch to some extent with impressions from the outside world *Muscular sense and co-ordination next become affected* Although still able to move the limbs or the head, movements are incoherent, and if at this stage the patient were put upon his feet he would stagger as he does in alcoholic intoxication A little later both tactile and special senses begin to be affected The patient is usually no longer cognisant of pain—if cut he would at any rate not have a remembrance of pain * *The special senses* are at this stage also lost one of the last to go being the auditory sense a point which is sometimes forgotten by those inclined to talk while anæsthesia is being induced *Muscle tone is the next function* to be lost, and at this stage all movements on the part of the patient should cease except those of respiration *The reflexes* disappear at varying stages the spinal reflexes, *e g* the knee jerks, disappear fairly early, probably before muscle tone is entirely abolished but certain other reflexes persist to a later stage Those which are of most interest to the anæsthetist are the conjunctival, corneal, and pupillary reflexes of which he will find full details in Chapter V

* This is rather an uncertain phenomenon Analgesia (loss of pain sensation without complete loss of consciousness) is not always present and procedures based upon the assumption that it is are not to be commended

Lastly, the *vital medullary centres*, respiratory, vaso-motor, and cardiac are overcome, and at this stage we have passed beyond the stage of a proper anæsthesia into that of overdosage In passing it may be observed that the level at which one endeavours to work is that indicated by the loss of muscle tone and of some of the reflexes, but the full activity of the medullary centres, and that an anæsthetic is good or bad according as it gives a wide or narrow margin between those two events

It is probable that anæsthetics have a selective affinity for nervous as compared with the other tissues to which they are equally conveyed by the blood In the case of one drug, this has been definitely proved by Nicloux, who estimated the amounts in mgms of chloroform present in various tissues of dogs killed by overdose The medulla oblongata heads the list with 85 mgms of the drug per 100 gms of tissue, the spinal cord approximates to it with 83 5 mgms The higher brain showed only 55 5 The distribution of the drug in the brain, if correctly demonstrated by this estimate, is peculiarly annoying, since it is our desire to give as much as we can to the higher centres, and as little as possible to the vital centres in the medulla Of the non nervous tissues, the highest figure is shown by the liver, with 50 5 mgms, and even the blood yielded only 70 mgms Ether and chloroform have for fatty substances a very definite affinity and the nervous system is peculiarly rich in lipoids, so that the figures given by Nicloux are not surprising

Upon the *peripheral nerves* anæsthetics have much less effect than on the central nervous system Faradisation of a *motor nerve* will in the deepest anæsthesia still cause immediate contraction of the muscles supplied by it, showing that the conductivity of the nerve is unaffected Of far more importance, however, is the fact

that the *sensory nerves* are not paralysed That pain is not felt by the patient is due simply to the loss of function of the cerebral sensory centres, *injury to the nerve still causes an impulse to be transmitted to the brain* Since no operative procedure can be carried out without more or less trauma (injury) to sensory nerves, we may picture the brain of the patient who is undergoing a surgical operation while under a general anæsthetic as being constantly bombarded by sensory stimuli which, though not consciously appreciated by the sleeping patient, are yet capable of producing reflex effects of a definite character, the importance of which to the work of the surgeon and anæsthetist it is difficult to exaggerate, and of which a condensed account will be found in the succeeding chapter

### EXCRETION OF ANÆSTHETIC DRUGS

On the cessation of the administration the exact reverse of the process observable during induction is seen The partial pressure of the anæsthetic in the alveoli falls below that in the blood and the drug passes out during expiration Similarly it passes from the tissues to the blood, until by a gradual process it is completely excreted It must be remembered that the process is a gradual one, more especially with ether and chloroform, and that immediately the administration ceases the patient does not regain control of normal function The necessity for careful attention continues until that control is re-established

### DRUGS ADMINISTERED BY METHODS OTHER THAN INHALATIONAL

Within the category of general anæsthetics there remain to be considered those drugs which are adminis

tered by other routes than the lungs, viz those given (1) by injection into a vein, and (2) by the alimentary system They are either liquid substances or solutions of solid ones Just as with inhalational anæsthetics they must reach and act on the nervous system The intravenous method requires little explanation The drugs are absorbed from the blood stream by the nerve tissues In the case of drugs given by the alimentary system, either by mouth or rectum, the process is analogous to that described for inhalational anæsthetics, from alimentary system to blood, from blood to nerve centres

The drugs in this group are mostly detoxicated in the liver and excreted by the kidneys

## CHAPTER II

### SHOCK AND ANÆSTHESIA

UNDER this short and convenient title we propose to discuss all the changes observable in the patient's condition, the causation of which can be traced to the surgical condition present or the procedure of the surgeon. The use of the term *shock* was at one time, and by some teachers still is, restricted to a definite clinical condition. The patient was described as lying pallid and almost pulseless, with dilated pupils, cold, sweating skin, and gasping, irregular respirations. In the view more generally taken to-day, that is but the extreme and final manifestation of a syndrome, which any patient who suffers trauma (whether inflicted accidentally or by the surgeon) exhibits in a greater or less degree, and from which general anæsthesia protects a patient to a very limited extent only.

Professor Crile, to whose work we owe so much of our knowledge on this subject, has said, "In general anæsthesia, part of the brain only is asleep." Though consciousness is abolished, many parts of the brain are quite capable of responding to *centripetal impulses* passed to the brain through sensory nerves injured by the knife. Certain changes have been demonstrated by Crile in cells of the grey matter of the brain as a result of such stimuli, and a further reference to the significance now attached to them will be found in a later part of this chapter. For the moment it is sufficient to say that such changes have

been discovered, and that their occurrence as a result of trauma is not prevented by inhalational anæsthesia These changes, though of the utmost interest scientifically, cannot be demonstrated clinically, and it is to alterations of *blood-pressure* and of *respiration* that we must look for clinical evidence of the effects of *shock stimuli*

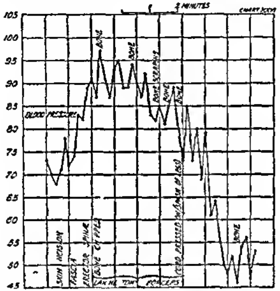


FIG 1 —Shock—Blood pressure of a dog undergoing laminectomy under general anæsthesia (Grey and Parsons)

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Broadly speaking we may say that during an operation each time the tissues are cut or lacerated a centripetal impulse is sent along a sensory nerve twig which affects reflexly both the level of the blood pressure and the depth and frequency of respiration That such changes do commonly occur is easily recognised by clinical observation, for the veriest beginner in anæsthesia soon learns

to expect a deeper, quicker respiration and a stronger pulse as soon as the operation has begun The details of these changes have been studied experimentally upon animals and upon the human subject by the use of the sphygmomanometer Fig 1 drawn from Grey & Parsons' Arris and Gale Lectures of 1912, shows a tracing from a dog undergoing laminectomy under general anæsthesia, and gives a good idea of the early evidences of shock

The curve of respiration is not shown upon the particular chart figured but its general course follows pretty accurately that of the blood pressure a fact well worth remembering in ordinary practice where B P records are not being taken

We may condense the results of much work on this subject under the following headings —

(*a*) Most stimuli from the field of operation cause a sharp rise of blood pressure followed by a sharp fall

(*b*) Successive stimuli delivered quickly one after another add their effects together, the total result being considerably greater than from one severe trauma

(*c*) After a time the pressor effect of stimuli begins to lessen the animal or patient wears out, and finally no pressor result can be obtained by the most massive stimulation the curve of B P steadily falls, the condition of full surgical shock is produced

(*d*) The tearing or pulling of tissues produces more powerful stimuli than the use of a sharp knife, and, therefore brings on the full condition of shock more rapidly

(*e*) Stimuli from some tissues cause much more reflex effect upon the organism than from other less sensitive structures This is well exemplified when an abdominal section is in progress Incision of skin causes immediate response in deepened respiration and higher B P , division

of the fascia very little effect If the muscle is divided by the knife, again little reflex effect is noticeable, but if it be stretched and split by the fingers, the response is powerful The parietal peritoneum, however delicately handled, is one of the most sensitive structures in the body, and, unless the patient is fully under at the stage both of opening and closing this layer, actual breath-holding or straining will occur On the other hand, incision or suture of the hollow viscera will cause practically no response, however light the anæsthesia, provided these structures, and their connections with the parietes, are not pulled upon

(*f*) Stimulation of certain selected areas, of which the spermatic cord is a well known but by no means the only example, results in an almost immediate fall of blood-pressure with little or no preliminary rise In the operating theatre we sometimes see faintness or syncope arising quite suddenly during operations in such regions This subject is explained more fully in Chapter XII, under the term " Reflex Syncope "

(*g*) While no general anæsthetic protects absolutely from shock stimuli, some anæsthetics give more protection than others Nitrous oxide is the most effective in this respect, its powers being two and a half times greater than that of ether, chloroform is even less effective than ether (*see* Fig 2)

(*h*) The claim made by the older generation of surgeons that shock could be prevented by the use of a *deep* anæsthesia, and that the occurrence of any ' Reflex syncope " was always a sign of too light an anæsthesia cannot be made good At the same time, it must be admitted that too light an anæsthesia does increase the likelihood of shock *Prolonged deep* anæsthesia, on the other hand, produces by itself a condition indistinguishable from shock,

with the single exception of that produced by nitrous oxide gas

(*i*) Operative shock is predisposed to by several factors, of which the following are the most important :—

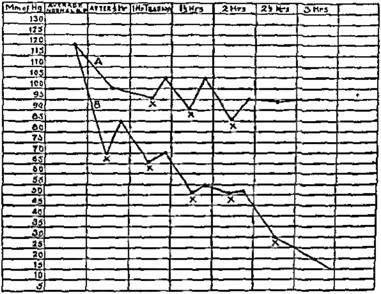



FIG 2—*Combined blood pressure chart, showing the average of a number of experiments*—A—Under nitrous oxide and oxygen B—Under ether At each spot marked × a trauma (burning of the paw) was inflicted (After CRILE)

(1) Hæmorrhage before or during operation
(2) Sepsis
(3) Fear
(4) Prolonged starvation
(5) Certain diseases, especially hyperthyroidism (exophthalmic goitre)

American anæsthetists, notably McKesson, have reduced to accurate figures the conception of the relation

between pulse rate and blood pressure, and the degree of surgical shock They give the following definitions —

*First degree shock* is that in which there is a 15 per cent increase in pulse rate without change in B P, or a 10 per cent decrease in B P without a decrease in pulse rate

*Second degree shock* is that of an increase of 25 per cent pulse rate along with 10 to 25 per cent decrease in B P

*Third degree shock*, which is the state clinically recognisable as surgical shock, is that in which the pulse rate is 100 or more, accompanied by a falling B P reaching the level of 80 mm of Hg systolic

A record of pulse rate and blood-pressure is kept throughout the operation, and the surgeon is warned when the second degree has been entered

## THEORIES OF SHOCK

So far as we have touched in the above upon theory, it has been theory which receives general acceptance and which accords with known clinical facts No one doubts that the most outstanding clinical feature in shock is lowering of blood pressure, nor that such lowering is the result of centripetal impulses passing to the central nervous system through the sensory nerves When we come to discuss the reason why the impulses cause the fall, we are in more debatable country Again we shall summarise —

(*a*) Criles' original theory was that the rises of blood-pressure seen in such charts as Fig 2 were due to reflex vaso constriction, and the subsequent falls to vaso-dilatation In complete shock, he supposed that the vasomotor centre was exhausted and could no longer respond to stimuli This theory we have been obliged to abandon since we now know beyond dispute that in deep shock the arteries are contracted, not dilated

(*b*) The essential cause of the fall of B P which is seen in fully developed shock is *diminution of the total volume of the circulating blood* The exact site to which the missing blood volume has withdrawn is not known It is not the splanchnic area, as was once supposed It may be the capillaries of the muscles, which are themselves in a state of profound relaxation

(*c*) The normal reaction of the blood is alkaline, and it remains alkaline even in deep shock, but what is termed the alkaline reserve is lessened, *i e* the blood is further on towards the stage of being acid than it normally is For a brief period the theory was held that this was, if hardly the essential cause of shock, at any rate a phenomenon of profound significance, and the practice of injecting alkalies into the blood stream was advocated We now know that this *acidosis* or diminished alkalinity is the result of oxygen starvation of the tissues The arteries being contracted, and the total volume of blood in circulation being diminished, it is obvious that the tissues must be short of oxygen, and Haldane's work enables us to ascribe the altered reaction of the blood to this lack

(*d*) Early stimulation and later exhaustion of the secretion of the adrenal glands was at one time advanced as an explanation of the blood-pressure curves seen in shock The theory was ingenious and plausible, but later research has disproved it The adrenal glands are not exhausted in the deepest shock

(*e*) Yandell Henderson advanced a theory that shock was due to exhaustion of $CO_2$ from the blood and tissues He pointed out that in the early stages of operations excessive depth and frequency was commonly observed in the respiration, and he proved that animals can be killed by pushing artificial respiration to extremes The theory is referred to again in Chapters III and IV, but it is not

now widely held to account for surgical shock in the ordinary sense, though it may possibly throw light upon certain examples of sudden collapse on the operating table to which the term syncope may more properly be given

(*f*) The heart muscle is not exhausted in shock If the volume of circulating blood be restored, as it can be by infusion, the heart will function again perfectly

(*g*) Certain substances, including histamine, are pro duced in crushed and lacerated tissues, especially muscle tissue To the absorption of histamine has been ascribed a series of symptoms resembling shock Recent experimental work by Blalock Bradburn and others throws doubt on this theory The point is only of importance to anæsthetists from the fact that cases which appear to be very severely shocked as a result of accidents sustained a few hours before the case is seen and in which limbs have been severely lacerated may pick up very rapidly after amputation under a good general anæsthetic In other words, once the immediate perils of the amputation are past, the outlook may be much better than one would at first sight suppose

(*h*) We should expect that the connecting link between the centripetal nerve impulses which cause shock and the fall of blood pressure which is its most striking feature, would be found in the central nervous system Crile and his co workers found changes in nerve cells which they believed to be peculiar to the conditions of fear, loss of blood, and surgical shock Later workers notably Mott, ascribed the changes solely to anoxæmia and so dis counted the importance of Criles work Rendle Short, on the other hand points out that the changes are not equally distributed in the central nervous system, but that much more marked changes are noticed in nerve

cells of those parts of the brain which are believed to govern *muscle tone* Now loss of muscle tone is a very marked feature of shock, and would of itself cause a fall of blood pressure and it is just possible, in Short's opinion, that here at last we may see some definite indication of the essential underlying causes of the phenomena of shock

Taking the above as a fair summary, the student will realise that much of our knowledge is negative, while another large moiety is speculative But one fact stands out which brings theory and practice into harmony, and that is that in shock the circulation is carried on in a partial and imperfect manner because the volume of the circulating fluid is seriously reduced If the volume be restored to normal by infusion, either of the blood of another person or of some neutral fluid such as will not be excreted by the kidneys and skin too rapidly, the heart will respond and the pressure return to normal Here we have the key to one of the essential features in the successful treatment of grave degrees of shock The details of this treatment are more suitably dealt with in a surgical rather than anæsthetic handbook but much of the preventive treatment of operative shock lies with the anæsthetist and we shall therefore say a few words about it

### PREVENTION OF SHOCK

There are many theories of shock, but only one anti shock technique which will bear examination Founding upon his own theory Crile about 1913 elaborated his ANOCI ASSOCIATION method of which the following are the leading features (*see* Fig 3) —

(a) *Prevention of fear* —Every member of the surgical team is taught the all important art of so dealing with the patient that no unnecessary fear is allowed to remain in

his mind That art does not consist in endless repetition of the phrase, ' Do not be frightened,' but rather in each so bearing himself or herself before the patient that he may gradually acquire the conviction that he is sur-

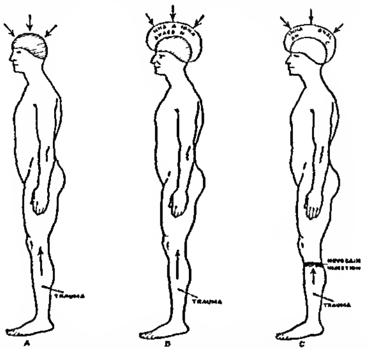



Fig 3.—Diagram (after Crile) to illustrate anoci association In A the trauma is inflicted on the leg and the brain being wholly unprotected considerable shock is suffered In B the brain is protected by inhalational anæsthesia from the effects of fear etc In C *the sensory nerves from the seat of trauma are blocked* by novocaine and the brain also protected by inhalational anæsthesia Theoretically no shock is suffered

rounded by careful kindly, and skilful persons who are doing for him what they do for hundreds of others and doing it with an expectation of his early and complete recovery so certain that they do not need to put it into

words unless definitely questioned Such an art is not acquired in a day, and some unhappy few are so constituted that they can never acquire it

As a further preventive of fear, and also for other reasons explained in Chapter IV, the patient receives a dose of morphia ($\frac{1}{4}$th grain, with $\frac{1}{150}$th grain atropine, *hypodermically) three-quarters of an hour before operation* Some surgeons go further, and give a sedative the night before operation *Veronal* gr viii was *the favourite* prescription of Prof Alexis Thomson of Edinburgh

(*b*) The sensory nerves are "blocked" by infiltration with novocaine By the systematic use of local in conjunction with general anæsthesia, the harmful stimuli from the area of operation are prevented from reaching the brain For the details of this measure the reader is referred to Chapter XXIII

(*c*) The anæsthetic of choice in Crile's practice is nitrous oxide and oxygen (*see* Chapter IX)

The whole of this technique has not been generally adopted as a routine but nevertheless the teachings of Crile have greatly influenced the mind and practice of most surgeons and anæsthetists Traces of that teaching are to be found everywhere in the organisation built up during the Great War to save as many as possible of the lives of badly smashed men At no previous time in the history of surgery was the problem of shock so pressing and the experience then gained has taught us much as to the handling of persons severely shocked by civilian accidents

#### TREATMENT OF SHOCK

*The treatment of a patient actually suffering from a* grave degree of shock and requiring an operation, from

the anæsthetist's point of view, may be classified under the following headings —

(*a*) The administration of $\frac{1}{6}$ or $\frac{1}{4}$ grain of morphia

(*b*) The intravenous injection of fluid, either normal saline or *gum saline* solutions, or *transfusion of blood*

(*c*) Attention to the warmth of the patient

(*d*) The choice of nitrous oxide and oxygen as the anæsthetic whenever possible

(*e*) The curtailment of the duration of operation to the minimum consistent with success

(*f*) The maintenance of an adequate supply of oxygen

## CHAPTER III

# ASPHYXIA (ANOXÆMIA) AND OTHER CHANGES IN THE BLOOD GASES

## PHYSIOLOGY OF THE RESPIRATORY CENTRE

THE student is no doubt conversant with the physiology of respiration but he is here reminded of certain facts in connection with the control of the respiratory centre, a due appreciation of which is vital to intelligent anæsthetisation of the human subject

To a limited extent the respiratory centre is controlled by *nervous* influences Firstly, there is the Hering-Breuer reflex, which does not appear to be of importance in anæsthesia Secondly, there is the *voluntary* control, which, of course, functions only up to the point when consciousness is abolished by the drug Thirdly, there is always the possibility of some *nerve reflex* affecting the centre A plunge into a cold bath, for instance, produces tremendous stimulation of the centre by centripetal stimuli of the skin nerves Similarly, even under anæsthesia, stimulation of sensory nerves may produce the most marked changes in respiration, which the student must be able to ascribe to their true cause if he wishes to be something more than a handicrafts man

Far more important than the nervous control is that exercised by the *blood gases* The centre is exquisitely

sensitive to the slightest change in the amount of $CO_2$ in the blood and alveolar air A trifling increase will lead to increased ventilation of the lung, the increase being mostly in the *depth* not the *rate* Similarly, quite a small fall of the $CO_2$ content of the alveolar air will lead to decreased depth of respiration or even to a temporary cessation (apnœa)

Alterations of the other essential blood gas, namely oxygen, also lead to changes in lung ventilation *Oxygen starvation* stimulates the centre to increased action, but the increase is in the *rate* more than in the *depth* of respiration, which becomes rapid, shallow, and later jerky and intermittent In the absence of oxygen the centre cannot long survive, a few gasps are noted, and then total cessation of all further effort

In actual practice, lack of oxygen is usually combined with $CO_2$ excess, though under the artificial conditions of certain forms of anæsthesia later to be mentioned, the former is present without the latter It will suffice for our present purpose if we state that $CO_2$ excess may possibly protect the subject for a brief period from the results of insufficient supply of oxygen, but that the protection is of limited utility only, and cannot be relied on as any real *safeguard* Possibly *it may* even be a drawback, as the continuance of action of the centre as a result of stimulation by $CO_2$ excess may mislead the inexperienced, and mask the fact that the patient is really short of oxygen, until a calamity makes apparent the true state of affairs

To understand the difference between the deep, urgent breathing caused by $CO_2$ excess and the quick, shallow breathing of oxygen want, is very important in any form of anæsthesia, in administrations of Nitrous Oxide and Oxygen it is absolutely essential

## ASPHYXIA OR ANOXÆMIA

This is by far the commonest blood gas change met with in anæsthetic work As usually seen, both $CO_2$ excess and oxygen want are present The actions of these two factors have been differentiated by various workers, and it has been definitely proved that the stimulation of the respiratory centre seen in the early stage of the condition is due to the $CO_2$ excess but that the remaining and more fatal symptoms are referable to lack of oxygen The term anoxæmia gives therefore, the most accurate description of the condition

It arises during anæsthesia from several causes In the first place the drug which the patient is inhaling and absorbing into the blood turns out from his red corpuscles a corresponding quantity of oxygen While this is only seen in its extreme form in the case of nitrous oxide gas, it is a factor acting even in the case of other anæsthetics Secondly during deep anæsthesia, the respiratory centre may be somewhat depressed and the force and frequency of the respiratory act diminished Thirdly, the respiratory passages may be partially or wholly occluded from *mechanical* causes This is far the most important type of asphyxia, being the most common the most fatal, and the most easily prevented

## COMMON CAUSES OF MECHANICAL ASPHYXIA

(a) Clenching of the Jaws arises not uncommonly during anæsthesia being specially frequent towards the end of the induction period Since a very large proportion of individuals have nasal passages insufficient in bore to carry the full volume of respired air, respiration must be obstructed if the jaws are clenched

(*b*) FALLING BACK OF THE LOWER JAW AND BASE OF THE TONGUE OVER THE EPIGLOTTIS.—This is always liable to happen after the muscles are deeply relaxed. Turgescence of the mucous membrane of this region may itself be the origin of an obstruction, and as explained later, will almost certainly occur as part of the vicious circle set up by an obstruction anywhere else in the respiratory tract.

(*c*) MUCUS OR BLOOD OR A FOREIGN BODY DRAWN BY INSPIRATION INTO THE AIR PASSAGES.—Changes of position of the head may release mucus which has been gathering in some parts of the mouth or pharynx. For instance, if the head has been lying on the side for some time, a pool commonly gathers in the most dependent cheek, and unless this is mopped out before the head is brought into the mesial position, this pool will be suddenly tipped backwards and very probably drawn into the larynx. Again, in operations upon the nasal or oral cavities, blood is always liable to be inspired, and not a few teeth have found their way into the air passages in the practices of dental surgeons who do not take precautions against this accident.

(*d*) SPASM OF THE ADDUCTORS OF THE VOCAL CORDS is one of the most common and most baffling incidents in anæsthesia. It announces its presence by the commencement of *laryngeal stridor*, a high pitched crowing noise, which is as annoying for the surgeon and anæsthetist to hear as the stridor itself is detrimental to the progress of a smooth anæsthesia. Inspired mucus or blood almost invariably sets it up, and the two conditions of fluid in the larynx and narrowing of the glottis from approximation of the cords add their effects together, with resulting obstruction of a high degree.

Laryngeal stridor, however, frequently occurs even

when no fluid has been inspirated It may be set up as a reflex from the area of operation Dilatation of the sphincter ani, and removal of the prepuce in circumcision are two common examples It may also undoubtedly be caused by giving too strong a vapour during the latter part of the induction stage Lastly, stridor may occur from no obvious cause at all, or to speak more correctly, from causes which are at present not known to us It is the authors' belief that one of these causes may prove to be *morphia* given as a preliminary to inhalational anæsthesia In our experience, stridor has been more frequent with morphia than without, particularly if chloroform be the anæsthetic chosen Beyond that we cannot at present go

(*e*) Pressure upon the Air Passages or Neoplastic or Inflammatory Swellings in the Neck —In such cases any obstruction which may exist before induction will probably become intensified during the process, and a complete arrest of respiration is not uncommon Large goitres are the most common type of neoplasm to give trouble, and all acute inflammatory conditions in the neck which extend towards the trachea are notorious for their tendency to give cause for anxiety during anæsthesia

## THE PHYSIOLOGY OF ANOXÆMIA

An animal subjected to asphyxia, either mechanically or otherwise, shows the following signs —

(*a*) *Increase of the depth and frequency of the respiratory movements of chest and abdomen* Even though there be a complete mechanical obstruction, increased efforts to breathe may still be made for some moments, although air no longer passes in and out of the chest In the deeply anæsthetised subject, this phenomenon may be very ill

marked, or altogether absent At the best, the respiratory centre under chloroform or ether soon tires if the air-way is obstructed, and ceases to respond to the stimulus of the gathering $CO_2$ Some work by Cushny in 1914 brought out clearly that in deep anæsthesia the centre hardly responded at all to increased $CO_2$ and his results were confirmed recently by Trevan and Brook

(*b*) There is usually a considerable rise of blood-pressure owing to a high degree of vaso-constriction Levy, when working on the subject, failed to obtain any considerable rise of blood pressure, other workers, however, have seen it

(*c*) The pupils dilate

(*d*) Generalised convulsions

(*e*) The animal succumbs finally from cardiac failure No heart muscle can continue to function properly if supplied by the coronary arteries with venous blood Moreover, the heart pump may have to act against the greatly increased peripheral resistance induced by vaso-constriction It must therefore be a matter of time only when the strongest and healthiest heart will cease to contract under the abnormal conditions of anoxæmia

(*f*) Venous engorgement

## CLINICAL SIGNS OF MECHANICAL ANOXÆMIA IN THE ANÆSTHETISED SUBJECT

The classical signs of asphyxia above described are hardly to be expected in the operating theatre, but essentially the condition of the patient who develops respiratory obstruction while under an anæsthetic is similar to that produced experimentally in animals in the laboratory The changes most easily observed are as follows —

(*a*) *Alteration of the colour* —Cyanosis shows itself

earliest in the lips, and the lobules of the ears—later the whole face becomes dusky.

(*b*) *Dilatation of the pupil*, which ceases to respond to the stimulus of light

(*c*) *The respiratory movements increase in depth and frequency* —The chest and abdominal walls may heave forcibly, but

(*d*) *The volume of air passing in and out of the glottis is diminished* —In complete obstruction, of course, none passes at all Persistence of chest movements is no proof of the passage of air in and out of the chest, that can only be proved by hearing the movement of air through glottis and mouth or nose, or feeling it on the delicate skin of the back of the observer's hand

Similarly, absence of chest movements is no proof that an asphyxia is not mechanical in origin In the unanæsthetised subject the respiratory centre always responds to the stimulus of $CO_2$ excess before finally succumbing, but when deeply affected by an anæsthetic, it may, as already explained, do so for a very brief period only It therefore often happens that the stage of heaving chest referred to in (*c*) is ill marked, and may not be observed at all

(*e*) *True convulsions are not seen* unless we may consider the jactitation of deep $N_2O$ anæsthesia as such (*see* Chapter VIII) Nevertheless, there are obvious and most valuable signs of asphyxia to be found in the muscular system, often quite early These consist in the incidence of *muscular rigidity*, which is frequently observed first in the muscles of the abdominal wall A surgeon performing laparotomy will notice at once the occurrence of this phenomenon, than which hardly anything can complicate and delay his task more effectively The anæsthetist who knows his work will, upon hearing from the

surgeon a complaint as to the rigidity of the abdominal wall, devote his attention first to securing a perfectly free airway before deciding that a deeper anæsthesia is required

### THE CLINICAL SIGNS OF NON-OBSTRUCTIVE ANOXÆMIA

Want of oxygen may develop in the patient apart from mechanical obstruction Most typically it is seen in nitrous oxide administered to a deep level of anæsthesia, without admixture with oxygen If given continuously upon a valved principle whereby the patient's own $CO_2$ is not conserved to him, we see a purer type of anoxæmia than in obstructive asphyxia, in that marked increase of blood and alveolar $CO_2$ is not present Pushed to overdosage, nitrous oxide causes the typical rapid respiration of oxygen want, ending suddenly in a few gasps and then total cessation

It must be remembered that oxygen want in itself is capable of producing loss of consciousness Moreover, a period of sub fatal anoxæmia is liable to be followed by a period during which the mental state is abnormal, and people recovering from anoxæmia are often amusingly irrational in their outlook Haldane quotes the case of a mine inspector who returned to the surface after exposure to a slight degree of anoxæmia in a mine after a fire He first of all shook hands very cordially with all the bystanders, and then offered to fight a doctor who kindly offered him the support of his arm We have seen similar incidents in the dentists' consulting rooms

Apart from obstruction and the inhalation of nitrous oxide, Haldane's work on anoxæmia brings home to us that want of oxygen in the tissues, particularly in the nerve centres, is the explanation of the symptoms seen in many conditions not hitherto much associated in our

minds with changes in the blood gases For instance, patients in whom the circulation is failing, frequently show quick, shallow respirations, which later become jerky and intermittent, even definite Cheyne-Stokes respiration may develop These changes are anoxæmic in origin, there is enough oxygen in the alveolar air, but the defective circulation cannot perform its due function of carrying it to the respiratory centre For the relief of such symptoms, the provision by the anæsthetist of an excess of oxygen in the inspired air can do something which will effect at any rate temporary improvement Conversely, to make such a patient breathe an atmosphere deficient in oxygen is greatly to reduce any chance he might otherwise have of ultimate recovery

## PREVENTION AND TREATMENT OF ASPHYXIA

Once asphyxia, especially mechanical asphyxia, has begun, it almost invariably tends to get worse The engorgement affects among other venules, those which run under the mucous membrane of the respiratory tract, still further obstructing the passage of air The muscular rigidity, moreover, soon manifests itself in the adductors of the vocal cords and the muscles which close the jaws, the patient has thus entered into a "vicious circle" (Fig 4) Mechanical obstruction to respiration immediately leads to diminished aeration of lung alveoli, this to diminished aeration of the blood The want of blood aeration has a double action *(a)* through the cerebral motor centres, causing muscular spasm, and for present purposes, spasm particularly of the masseters and adductors of the cords, and *(b)* venous engorgement of the mucous membranes of the respiratory tract, both of which further increase the mechanical obstruction It is

evident that the prevention of the earliest signs of asphyxia is to the anæsthetist a matter of vital interest. The cardinal points to watch are as follows :—

(*a*) Keep the neck of the patient as far as possible in a natural position, *i.e.* do not either flex or extend

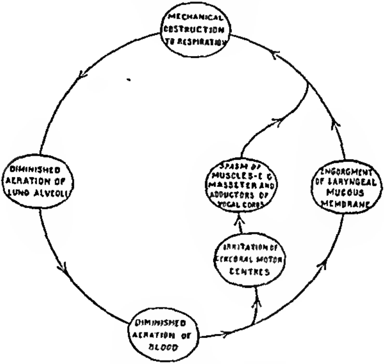



FIG 4 —Vicious circle of asphyxia

the head unduly upon the body unless the nature of the operation demands such an unusual position.

(*b*) Maintain a free passage for air either through the nose or the mouth

(*c*) Keep the lower jaw in good position throughout the administration.

(*d*) Avoid turning the face from the lateral to the dorsal (face up) position unless essential If it has to be done, be careful first to mop out any "pool" from the dependent cheek

(*e*) Deal as effectively as possible with the earliest appearance of laryngeal stridor

Let us see how in a normal case these rules can be applied With the patient lying (or, in exceptional circumstances, sitting) in a comfortable position, the shoulders and head raised above the rest of the body and the face looking upwards (or straight forwards, in the case of the sitting patient), the anæsthetic is begun slowly, and the patient encouraged to take his time and to breathe naturally At this stage the jaw needs no support, the muscles being neither relaxed by deep anæsthesia nor spastic from asphyxia With the advent of muscular relaxation the head is usually turned to one side, that which is opposite to the side on which the surgeon will be working being chosen In cases, however, where the patient is stout and short necked, the turning of the face to the lateral position may of itself, lead to respiratory obstruction by narrowing the laryngeal bore This is particularly liable to occur if the neck be over extended It may, however, cause embarrassment even in the absence of over extension In such cases it is better to maintain the dorsal position We must now determine whether the patient can breathe best through the mouth or the nose and make sure that the channel chosen is as free as possible In the majority of cases it will be found that respiration is oral, and that all that is necessary is to support the lower jaw by a finger hooked into the depression just below the symphysis mentis The hands of the anæsthetist, therefore, take up a position from which in nine cases out of ten they will never require to be moved

*The hand of the side toward which the patient's face is turned* supports the jaw and keeps the face-piece or mask adapted to the face The middle finger is pressed into the space below the symphysis mentis, and *exercises traction forwards and a little upwards,* thus preventing the jaw from slipping backwards, the index finger lies along the lower part of the mask, maintaining adaptation between it and the chin, the thumb bears on the mask higher up, keeping its upper part pressed against the

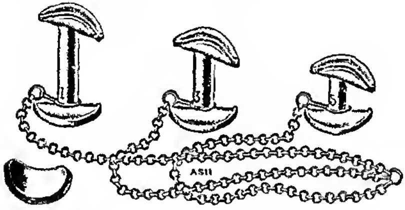



FIG 5 —Hewitt's dental props

bridge of the patient's nose and also serving as a *point d'appui*, or fulcrum, from which the jaw traction by the middle finger can conveniently be exercised This grip once learnt is not fatiguing to the hand, and is in the authors' opinion one of the essential points for the beginner to master (*see* Fig 32(c), page 129)

*The opposite hand* holds the drop bottle, if the method in use is an open one, the wrist resting upon the uppermost side of the patient's head

Fig 32(c) shows this grip in operation, while Fig 33(D) shows the alternative frequently adopted This alterna-

tive has various disadvantages It covers up a larger part of the patient's face than the method recommended, and it tends to tilt the mask sideways The little finger is supposed to be hooking forward the jaw by pressing behind its angle, and such a method is very fatiguing if in use for more than a few moments

In a proportion of cases it is found that a free air-way cannot be maintained by these simple measures Upper or lower teeth (or both) may be missing and traction upon the lower jaw only closes the mouth the more firmly In most of these cases the difficulty can be met by the use of the *dental prop* These are made in various sizes and shapes, of which the best known are Hewitt's and Bellamy Gardner's (*see* Figs 5 and 6) The latter are made of aluminium and are of small size only

Scale 2/3

FIG 6 —Bellamy Gardner's dental props.

They are useful for patients who retain most of their own teeth, but whose jaws are of the receding type and not easily kept forward In such persons the prop acts as a rocker on which the jaw can be *rolled* forward Hewitt's props are of plated metal, with lead on the cups to avoid injury to the teeth They are made in five sizes, of which the middle and larger are very convenient for cases in which one or both rows of teeth are missing

For cases entirely without teeth, and in which a large flabby tongue is prone to fall back over the epiglottis, the mouth tube (Fig 7) is very convenient The rubber shank lies along the top of the tongue the metal end lies between the gums As originally introduced by Hewitt, the air way was circular in cross section, but the flattened model figured is a distinct improvement It was intro-

duced by Dr Phillips An ingenious modification of this air-way has been introduced by Clausen (*see* Fig 7A) Its principal features are (*a*) a small bore inlet tube for connection with a Shipway or similar vapour inhaler, by means of which the anæsthetic vapour is conducted to the distal end of the air-way, and (*b*) the outlet of the air-way is connected up to a length of rubber tubing, so that the expired air laden with anæsthetic vapour may be conducted away from the operator and anæsthetist

Fig 7—Phillips modification of Hewitt s artificial air way

By its use the anæsthesia becomes an endo or intra pharyngeal one

Occasionally one decides to facilitate nasal rather than oral breathing, and if the natural passages are inadequate, recourse may be had to the nasal air way introduced by Dr J F W Silk This is a straight rubber tube of fairly firm texture (*see* Fig 8), some seven-sixteenths of an inch in diameter, and about seven inches in length Naturally, the larger the calibre of the tube which can be passed, the more free will be the resulting air-way First lubricated with vaseline, the tube is passed along

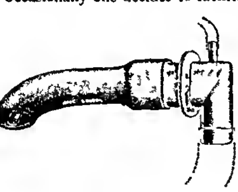


Fig 7A—Clausen s air way

one nostril until its bevelled end passes out from the posterior nares and comes to rest just behind the base of the tongue, and just above the glottis The exact depth to which the tube should be passed in the individual case should be ascertained by testing the ease with which air is passing up and down, and a safety pin may be passed so as to mark the optimum position and prevent the tube slipping inwards

If proper and timely use be made of one or other of these simple devices, the use of the tongue forceps is rarely necessary, and, because of the damage it is liable

FIG 8 —Silk s nasal tube

to cause, is to be discouraged Occasionally, however, it may be required and a suitable appliance should always be at hand for an emergency Figs 9 and 9A show two types The little clip of Mr Bellamy Gardner is preferable to the ring type the passage of the spike through the tongue substance producing less after-pain than the bruising following the use of the other instrument

Before using either mouth prop or tongue forceps, it is occasionally necessary to use some mechanical means to lever open a tightly clenched jaw The earlier one interferes in a case of mechanical asphyxia, the less necessity will exist for the use of such means Fig 10 shows two well known mouth gags, and also a boxwood

wedge, the use of which is less liable to injure teeth than a metal instrument. If a gag is used, the blades when

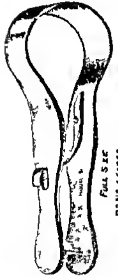


Fig. 9.—Bellamy's Gardner's tongue-clip

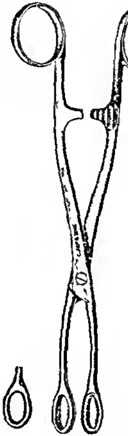


Fig. 9A
Ring tongue forceps

closed should lie the one behind the other not side by side. This ensures a minimal thickness to be inserted between the tightly clenched teeth.

## TREATMENT OF LARYNGEAL STRIDOR

This is of necessity difficult since the causation of the condition is in many cases obscure *The error* common to most beginners, and to many who would resent such a title being applied to them, is to regard the appearance of stridor as an indication to *deepen the anæsthesia* Whether the cause lie in local irritation of the laryngeal mucous membrane or in some stimulus

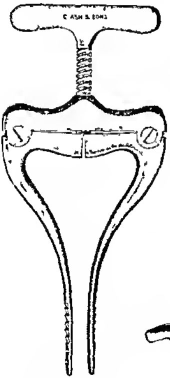


Fig 10
Wedge for opening jaws

Fig 10A
Mouth gag

Fig 10B
Boxwood wedge for opening jaws

from the area of operation, the condition is presumably always essentially a reflex spasm of the adductors of the vocal cords but it is a *reflex which may persist even in an anæsthesia so deep that the vital medullary centres are in peril*

The preventive treatment consists chiefly in following the other rules set forth above for the prevention of asphyxia with such faithful care that the patient never enters into the vicious circle of asphyxia of which stridor is so prominent a feature Patience in the induction stage—the avoidance of *forcing* the anæsthetic upon the patient—is a safeguard not to be forgotten

Once the condition has arisen, it saves time to *withdraw the anæsthetic* altogether, and to allow the patient to breathe nothing but fresh air Brisk friction of the lips with a rough towel often does good, presumably by setting up a "cross reflex" In severe cases, a most valuable measure is the inhalation of pure oxygen, a cylinder of which should always be at hand in the operating theatre Even an obstructed air-way will convey enough undiluted oxygen to reduce the venosity of the blood, and so cut across the vicious circle

## OTHER ALTERATIONS IN THE BLOOD GASES

Up to the present we have discussed alterations in the blood gases chiefly from the point of view of oxygen want Something, however, remains to be said from the point of view of the anæsthetist upon the subject of $CO_2$ want and excess

Apart from its action as the normal regulator of the respiratory centre, a certain proportion of $CO_2$ is necessary in the economy Starling and his assistants have shown that in the presence of real $CO_2$ want, the circulation

cannot be effectively carried on, and Henderson in his "acapnic" theory of shock advanced at one time the suggestion that collapse on the operating table was commonly due to the excessive respiration sometimes seen under ether not very well given. Certain facts to which Henderson pointed in support of his theory are not in doubt; briefly they are as follows:—

(*a*) Experimentally, if one practises excessive respiration (*hyperpnœa*) for as long as nature permits, the $CO_2$ in the blood and alveoli is so reduced that further respiration is impossible and a period of *apnœa* ensues which persists until a sufficiency of $CO_2$ has again gathered. A resolute experimenter can push the period of hyperpnœa to such lengths that he feels very faint and giddy, and shows definite cyanosis before the apnœa terminates; in other words, he is short of oxygen before he has gathered in his alveoli enough $CO_2$ to enable his respiratory centre to work.

(*b*) In the laboratory the above experiment has been pushed to its logical conclusion, and animals have been killed by the simple process of administering to them artificial respiration to excess.

Doubtless hyperpnœa does sometimes occur under anæsthesia, and if the method in use be an "open" one, temporary lowering of the $CO_2$ in the blood and alveoli must result, but several observations lead us now to suppose that in such cases Nature applies her remedy of apnœa (or in less extreme instances, a period of reduced lung ventilation) in time to prevent serious consequences. Blood analysis has demonstrated that even after long administrations the patient's blood always contains a sufficiency of $CO_2$. Moreover, the air under open ether masks—and it is precisely this method of anæsthetising which Henderson believed prone to cause acapnia—has

been analysed, and shown to contain so high a proportion of $CO_2$ as to preclude the possibility of the patient developing $CO_2$ starvation In one method only of anæsthetising do we believe that anything corresponding with Henderson's acapnia ever occurs in anæsthesia This point will be dealt with in the succeeding chapter

Lastly, $CO_2$ *excess* may be present without oxygen want In the re-breathing method mentioned in the next chapter, the contents of the bag may be kept as rich in oxygen as desired, if a cylinder of the gas is available It therefore behoves us to remember that with such a system we must still guard against real excess of $CO_2$ consequent upon repeated respiration of the same atmosphere Our guide will be the *depth* of respiration If we continue with re breathing to a point when the type of respiration corresponds with that which would indicate real distress in the unanæsthetised subject (a point which is reached when the inspired air contains some 6 per cent of $CO_2$), we are doing harm instead of good We may excite the vomiting centre and damage the circulation at the moment, and if recovery takes place we may find that we have given the patient a very severe headache

## CARBON DIOXIDE AS AN ADJUNCT TO ANÆSTHESIA

Of recent years, as a result of the researches of Haldane and Yandell Henderson, the stimulating effect of $CO_2$ on the respiratory centre has been utilised in anæsthesia It has been proved experimentally that the addition of 3 per cent $CO_2$ to the inspired air causes the depth of respiration, *i e* the volume of air taken in with each breath, to be doubled, with 5 per cent $CO_2$ it is increased about four times It may readily be seen of what immense advantage this is in controlling respiration during

anæsthesia, both in hastening the intake of anæsthetic vapour during induction and its excretion at the end of operation. The employment of closed inhalers had enabled the anæsthetist unwittingly to take advantage of the principle, but in a somewhat haphazard fashion. The increased $CO_2$ in the re-breathing bag certainly operated during induction, resulting in deeper respiration, but, unfortunately, it continued to operate so long as the closed method was in use, not entirely to the surgeon's convenience.

The late Dr. S. R. Wilson, of Manchester, was a strong advocate for the use of $CO_2$ during anæsthesia, and did much to popularise it in this country, for three specific purposes: (*a*) during induction to hasten the arrival of deep anæsthesia; (*b*) at any period in the course of administration if there arise the need for increased depth of respiration in order more quickly to deepen the anæsthesia; (*c*) after the cessation of the administration to facilitate the excretion of the drug The principle has been utilised chiefly as an adjunct to ether anæsthesia, but, of course, it is equally applicable in the case of any other inhalation anæsthetic.

Wilson made use of cylinders containing oxygen, to which 5 per cent. or more $CO_2$ had been added, and mixtures of this nature serve admirably, the outlet nozzle of the cylinder being fitted with a rubber tube by means of which the Oxygen-$CO_2$ mixture is led under the mask, or, if preferred, through a bag controlled by valves. The weight and bulk of such cylinders immediately suggest themselves as serious inconveniences, and Mr. Whitridge Davies introduced a very ingenious improvement. Instead of employing combinations of oxygen with $CO_2$ he made use of pure $CO_2$, and with the co-operation of Messrs. Sparklets, Ltd., obtained metal capsules, 6½ inches in

length, containing 25 grammes of liquid $CO_2$, providing approximately 25 litres of the gas By inserting one of

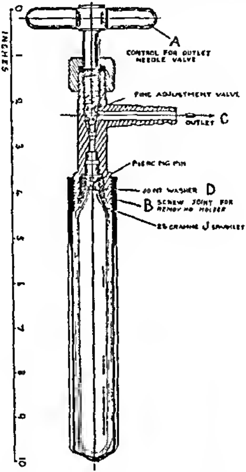



FIG 11 —Whitridge Davies apparatus for supply of $CO_2$

these into a container with a fine adjustment valve, the soft metal at one end of the capsule is pierced and the

gas liberated at will, and at whatever rate of flow is desired, by means of the control handle A rubber tube is connected to the outflow nozzle and conducts the gas to mix with the inspired air The whole apparatus is easily carried in an ordinary bag, measuring no more than 10 inches in length No attempt is made at obtaining known percentages, observation of the requisite depth of respiration being sufficient control During induction of anæsthesia the rubber tube is led under the anæsthetic mask and sufficient $CO_2$ allowed to flow adequately to increase the depth of breathing In this way the intake of anæsthetic is very considerably hastened, and the induction period commensurately shortened For the purpose of hastening the excretion of the anæsthetic it is better to connect the rubber tube with a rubber nasal tube or the inlet tube of a Clausen s air-way By this means the anæsthetic vapour passes out into the atmosphere and is not re inhaled by the patient to any extent

It is well to bear in mind that $CO_2$ however given, should not be used in concentrations above 3 per cent in the inspired air Even lower concentrations achieve all that is desired viz a slight increase in the volume of respiration Further, in respiratory failure occurring during anæsthesia it may be positively harmful to employ $CO_2$ An already exhausted respiratory centre will not respond to such a stimulus

## CHAPTER IV

### METHODS OF ANÆSTHETISING

In inhalational anæsthesia certain terms, such as "open method," "closed method," etc, are used in describing different systems of anæsthetising, and it will save time later if these are now defined and a few words added to indicate their bearing upon the questions dealt with in the foregoing chapter

The Open Method is one in which the drug is dropped or poured upon a fabric stretched on a mask which does not lie in close apposition to the face If the student will experiment with such a mask as Schimmelbusch's, he will find that by no effort can he make its whole circumference touch his face at the same time Anæsthetics vaporised from such masks must of necessity be inhaled freely diluted with fresh air These masks are only suitable for use with chloroform

The Perhalation Method —This term is not used often, but it is the most strictly correct name to give to the process commonly called "open ether" If the student will examine Bellamy Gardner's open-ether mask (Fig 30) he will find that it is deliberately shaped to lie over its entire circumference in close apposition to the face of the average patient In actual use it is well, however, to make sure of this apposition by the use of a ring of gauze, as shown in Fig 32(b) Upon the mask is stretched gauze of a thickness just as great as will permit free respiration to take place through its layers

The whole bulk of the respired air must pass *through the fabric*, none escaping between the face and mask

The term "SEMI OPEN" is applied to various methods now rarely seen One of the best known of these was the anæsthetic cone, still used by a few for C E mixture

Granted a free air way in the patient himself, there is in none of the foregoing methods anything which should seriously upset the balance of the blood gases The oxygen of the atmosphere is freely available, and the conditions are such that excessive loss of $CO_2$ sufficient to cause acapnic collapse is not in question

The term 'CLOSED METHOD' is applied to one in which the patient breathes in and out of a closed bag The Clover and Ormsby inhalers are "closed" instruments With this method the patient rapidly uses up the oxygen of the contained air, and accumulates considerable $CO_2$, life could not be sustained for any long period of time under such a system Oxygen must be supplied from time to time by permitting say, one breath in five to be taken from the fresh air instead of from that in the bag Alternatively oxygen from a cylinder may be supplied by an accessory pipe into the inhaler

This method is also referred to as the RE BREATHING METHOD Hyperpnœa with this method does *not* lower the $CO_2$ in the alveoli and is therefore *not* followed by apnœa

The VALVED METHOD is used with "gas" or "gas-oxygen, and with a few special ether and chloroform inhalers The facepiece fitting accurately, the patient draws all the volume of his inspiration from the inhaler, his expirations he propels through a valve into the general atmosphere of the room If nitrous oxide unmixed with oxygen is being given the patient suffers from oxygen starvation even more rapidly and completely than in the

re breathing method During the induction period of gas anæsthesia, such oxygen starvation is practised deliberately, and if not pushed too far is harmless It cannot, however, be continued for more than a brief space of time The admixture of oxygen to the gas being breathed entirely abolishes this unfavourable feature

There is, however, another consequence of the use of "valves" which is unaffected by the addition of oxygen Reference has already been made to *Yandell Henderson's acapnic theory*, and if under any form of anæsthesia the patient can be reduced to a condition of *$CO_2$ starvation*, it will be when the valved system of administration is in operation for a prolonged period As a matter of experience, patients breathing 'on the valves do often exhibit shallow respirations and slight pallor which is rapidly and very strikingly remedied by turning to the re breathing method One can hardly doubt that the improvement is due to a gradual re accumulation of carbon dioxide in the blood and tissues

The discovery of Bohr that lack of $CO_2$ *causes the hæmoglobin of the blood to hold on more tightly to its oxygen*, throws much light upon this question From this work, it is evident that if $CO_2$ is reduced by excessive and prolonged valvular breathing, even a patient with a good colour may, so far as his nerve tissue is concerned, be really suffering from oxygen starvation, since the hæmoglobin refuses to give up its charge of oxygen Since becoming acquainted with Bohr s results, our preference for a method of gas-oxygen administration which admits of some degree of re breathing, has been greatly strengthened

Two other terms referring not to the type of inhaler, but to the method of supplying the drug, are in use

By the "DROP" METHOD we mean one in which the anæsthetic is supplied in a steady series of drops The

flow may be quick or slow, but it always arrives on the mask in isolated drops of uniform size Such a method demands more constant attention than the next to be described, but it is capable of yielding that even uniformity of vapour strength so desirable in open methods

The DOUCHE METHOD is unfortunately far more commonly used by those whose attention has never been drawn to the significance of the difference between the two Supplies of the drug rendered, say, every twenty seconds cannot possibly give an even vapour strength

In VAPOUR METHODS we vaporise a fluid anæsthetic such as ether before it reaches the immediate neighbourhood of the patient's face, instead of expecting the patient to carry out that process by force of his own inspirations There is a good deal to be said in favour of relieving him in that respect and several examples of modern vapour methods will be found described in later chapters

'SINGLE DOSE' methods are of use chiefly in dental surgery The patient is charged up with the anæsthetic, and the operator has to begin his work as soon as the mask is withdrawn from the face, ceasing as soon as the patient shows any signs of recovering consciousness of pain

Single dose anæsthetics are in a class by themselves In order to achieve success with them special experience on the part of the administrator and mutual confidence between operator and anæsthetist are essential

The period of anæsthesia available to the operator which any particular single dose" anæsthetic may be expected to yield is obviously a matter of the first importance, and the table given in Chapter XXII will be found helpful in this connection

## CHAPTER V

## THE CLINICAL OBSERVATION OF THE PATIENT

### STAGES OF ANÆSTHESIA

ANÆSTHESIA has been divided into four clinical stages corresponding to the degrees to which the nervous system has been affected. The boundaries between these stages are often ill defined, but the terminology has some value as facilitating description.

THE FIRST STAGE lasts from soon after the commencement of inhalation until the establishment of involuntary regular automatic respiration. In older text books it was said to be characterised by struggling, shouting and breath holding. With a patient not addicted to alcohol and with the anæsthetic skilfully administered this description is unduly lurid.

THE SECOND STAGE is the stage of light anæsthesia.

THE THIRD STAGE is the stage of deep anæsthesia.

THE FOURTH STAGE is that of overdosage.

### THE OCULAR REFLEXES IN ANÆSTHESIA

These give such valuable assistance to the anæsthetist that it will be well to define and describe them as a preliminary. They are three in number.

THE CONJUNCTIVAL REFLEX is best elicited by drawing the upper lid upwards from the eyeball and retaining it in that position with one finger, while with another

finger the ocular conjunctiva is lightly touched in the area of the inner canthus If the anæsthesia is very light, both lids attempt to approximate and close the palpebral fissure The upper lid may slip down from under the retaining finger and come into its proper place, while the lower lid is elevated At a deeper level of anæsthesia there is not complete action of the orbicularis, but merely of a certain part of it, so that all that is observed is a *twitch inwards of the lower lid* Even this form of the reflex disappears before the corneal reflex

THE CORNEAL REFLEX is elicited by pushing up the upper lid by one finger and with the pulp of the *same* finger lightly touching the centre of the cornea as soon as it is exposed, when we feel or see the upper lid come back into position with a sharp definite twitch The examining finger must be slipped smartly out of the way as soon as the cornea has been touched Even in deep anæsthesia, a trace of this reflex can usually be elicited if the little manipulation be properly performed

The conjunctival and corneal reflexes are frequently confused in the mind of the student The most common mistake made is to pin the upper lid firmly somewhere in the region of the bony roof of the orbit, to dab the eye far too vigorously, and to believe that no reflex is present because no movement of the upper lid takes place In the first place the upper lid cannot move if it is rigidly held against a bony plate, in the second place, it is wholly unnecessary to inflict upon the cornea more than the lightest of touches Both these reflexes are to be used with great discretion undue frequency and excessive vigour of touch being alike capable of setting up serious inflammatory reaction

THE PUPILLARY LIGHT REFLEX is elicited by shutting off light from *both* pupils for ten to twenty seconds, and

then smartly withdrawing the protecting fingers and allowing as strong a light as possible to fall on to the eye Additional delicacy in this test may be obtained by opening one eye, say the left, and, while closely observing this pupil, opening the right eye, the pupil of the left eye will then be seen to contract if any light reflex be present The response of the sphincter pupillæ should *always* be present, its absence is a certain indication of something wrong, some sluggishness may be permissible under ether, but even that is suggestive of trouble if chloroform is the anæsthetic

The use of a preliminary hypodermic of morphia tends to make the pupil somewhat smaller than normal, and of atropine somewhat larger than normal, and to elicit the light reflex it may be necessary to cut off illumination for a somewhat longer period than if no morphia or atropine had been given Nevertheless, with a little care, the light reflex should always be capable of demonstration even in the morphinised or atropinised subject

## THE OBSERVATION OF A NORMAL CASE

In the case of nitrous oxide and of ethyl chloride, the patient passes through the various stages very rapidly, and the picture of anæsthesia as induced by either of these two is therefore best described separately The following may be taken, therefore, as an account of what is to be observed in the patient inhaling ether or chloroform, unless a specific reference is made to one of the other anæsthetics

First Stage —The first sign that some effect is being produced in the patient is usually the movement of swallowing, the hyoid and thyroid can be felt or seen to be moving in conjunction with the muscles of deglutition The respiration often tends at first to be

shallow and irregular, slight pauses occur, usually after an inspiration. Serious holding of the breath rarely occurs unless as an accompaniment of struggling, if it does occur to a degree which causes any blueness of the face (cyanosis) it usually calls for the removal of the anæsthetic for a moment until normal breathing has been resumed.

The pulse, conveniently taken on the facial artery just where it comes round the ramus of the jaw, is usually somewhat rapid from excitement. The colour of the face rarely departs much from normal.

The eyes may be opened as the first stage progresses, and the eyeballs tend to rotate. The pupils are large, but react sharply to light. Both conjunctival and corneal reflexes are present.

The muscles are often rigid, and this, with the slight irregularity in breathing, may be all the evidence of "excitement," the name sometimes given to this stage. On the other hand, in very nervous patients, and in the alcoholic, the stage is often characterised by struggling, shouting, and breath holding, during which cyanosis supervenes. These symptoms are frequently followed by a period of deep breathing, when all the anæsthetist's judgment is required to regulate the dosage of anæsthetic, and to prevent, if chloroform be the drug, the onset of cardiac or respiratory failure. It is well, as struggling subsides and deep breathing commences to withdraw the anæsthetic for a few breaths until all trace of cyanosis disappears.

THE ONSET OF THE SECOND STAGE—that of Light Anæsthesia—is marked by the regular, deep, automatic type of respiration which succeeds the shallow and perhaps irregular breathing of the first stage. The rate is usually increased.

The pulse tends to become slower while maintaining its volume The colour varies somewhat with the anæsthetic in use With ether there may be a slight flush possibly a trace of cyanosis if the method is a closed one With chloroform the colour should be about the patient's normal

The eyelids are now closed and the eyeballs at rest, usually looking slightly downwards The pupil is medium in size and reacts briskly to light The conjunctival and corneal reflexes are both brisk

The muscles though quiescent, are not completely relaxed For this reason the second stage, while sufficing for many surgical operations is inadequate for an abdominal section

THE THIRD STAGE is that of Deep Anæsthesia

In this stage the breathing remains regular and of increased rate, but is decidedly shallower than in the previous stage

The pulse is regular and usually somewhat smaller in volume, particularly in chloroform anæsthesia, when a degree of pallor is also present With ether there may persist a slight flush

The pupil is now more contracted and the response to light more sluggish It should, however, always be possible with careful observation to discern some degree of light reflex The conjunctival reflex is abolished and the corneal reflex also absent or only faintly discernible

The muscles are now well relaxed This is the stage demanded for the performance of abdominal operations, and any others wherein complete muscular relaxation is requisite

Broadly speaking, then, the third stage is characterised by (*a*) full regular respirations, (*b*) colour not much removed from normal, (*c*) moderate sized pupil which

reacts to light, (*d*) conjunctival reflex absent, (*e*) corneal reflex faint or absent, (*f*) relaxed muscles these may be regarded as the signs of fully developed surgical anæsthesia

FOURTH OR DANGER STAGE is the stage of overdosage and is, of course, never entered voluntarily

The respiration, though definitely weakened, may show occasional deep gasps

*The pulse is small and irregular, usually rapid The face is pallid or may, where respiratory failure is predominant, be deeply cyanosed*

The eyelids are often apart and the eyeball staring and glassy, from cessation of the lachrymal secretion The pupils are dilated, in severe cardiac failure usually widely so The conjunctival and corneal reflexes are absent The muscles are flaccid

Cessation of respiration and circulatory failure, from failure of the medullary centre, are the closing phenomena of overdosage

## ABNORMAL PHENOMENA IN ANÆSTHESIA

It is not intended to furnish here any account of matters more suitably treated under the "Accidents of Anæsthesia," which are fully described in Chapter XVIII, but merely to draw the attention of the student to certain departures from the normal course of anæsthesia which are encountered with varying frequency, to ascribe them as far as possible to their true causation, and indicate methods of prevention

The abnormalities fall into two classes, those connected with the nervous and muscular systems, and those in which respiratory changes are evident

## MOTOR AND NERVOUS SYSTEM

*Clonus or tremor* sometimes appears in one or more limbs, even the trunk being affected in severe cases. Ether is practically the only anæsthetic under which the tremor ever appears, and the condition is often spoken of as "ether tremor." It rarely appears in the female subject, being almost limited to powerfully built young men. Coming on in the second stage, it frequently persists in the deepest of third stages, and in bad cases there is usually no option but to change over to chloroform—always supposing that the tremor will interfere with the work of the surgeon. If it will not, the condition calls for no active treatment, since it is in itself not dangerous.

*Movements recalling to the observer the condition of athetosis seen in the limbs of hemiplegics* are occasionally seen in the anæsthetised patient. The finger of a hand may be slowly moved, or one or other shoulder may be shrugged. The exact cause of these movements is obscure. They occur in all types, both sexes, and at all ages; they are *not* necessarily asphyxial, though a trace of asphyxia seems sometimes to conduce to them. They persist for some time after the third stage has been entered, and ultimately disappear without any obvious cause other than the passage of time. It is rare for them to continue more than five or ten minutes after full anæsthesia has been induced. Their practical importance lies purely in this, that the inexperienced anæsthetist, observing some muscular movements still persisting, may take them as an infallible sign that anæsthesia is not complete, and may deliberately take his patient to a deeper level. If in doubt, the anæsthetist must, of course, consult all the other recognised guides, such as the eye reflexes, but once he has seen these movements in a case, and had demon-

strated to him *their slow, rhythmic character*, he is not likely to be misled on a future occasion

*Muscular rigidity* has been mentioned already in Chapter III When it persists in a patient in whom other signs suggest that a full anæsthesia has been produced, the anæsthetist will usually find that attention to the air way, and perhaps a whiff of oxygen, will remedy the trouble

## RESPIRATORY ABNORMALITIES

The explanation of many variations in the depth, force and frequency of respiration is to be found in alterations in the blood gases, and the student is referred to what was said on the subject in Chapter III

*Increased depth* is due —

(*a*) To increased $CO_2$ This can only occur (i) if the air-way be obstructed or (ii) if a closed method has been used and re breathing has been pushed to excess In either case the remedy is obvious

(*b*) To stimuli from the work of the surgeon In this case a quick glance at the site of operation or a question addressed to the surgeon will supply the explanation If the type of respiration indicate a really inadequate level of anæsthesia, the anæsthetist should ask the surgeon to wait a few minutes while the level is deepened In any case, one must remember that if the method is an open one, a period of quiet breathing must necessarily follow (*vide infra*)

*Increased rate* is a much more serious matter, for it probably indicates anoxæmia the cause of which must be sought out and remedied if possible

*Shallow breathing* or even slight temporary arrests of respiration arise frequently During the induction stage they may be due to —

(*a*) Apnœa or acapnia following voluntary excessive breathing

(*b*) Using morphia before chloroform (*see* page 61)

At a later stage it may be due to —

(*a*) Acapnia following excessive breathing excited reflexly from the seat of operation Acapnia is not now generally regarded as a feasible explanation of many failures of pulse and respiration under anæsthetic, as has already been explained on pages 14 and 38 If, however, in light anæsthesia under an open method, there has been excessive stimulation of respiration from painful impulses originating in the field of operation, a period of quiet breathing, perhaps even complete apnœa, must necessarily follow, as there will have been undue excretion of $CO_2$, and time will be required for it to gather again in the blood and the alveolar air

(*b*) Direct reflex inhibition of the respiratory centre An example of this is seen sometimes when the bladder is over-distended by lotion

(*c*) Impending vomiting, due to too light an anæsthesia

*Moist sounds* not uncommonly appear The student's general knowledge of medicine will enable him to decide whether the fluid is likely to be in the pharynx, larynx, trachea, or bronchi If in one of the first two named, it will suffice to swab out the throat and encourage the patient to cough If, however, moisture is evidently present in the trachea or bronchi, the condition is one calling for considerable care and judgment It arises more commonly with ether than with chloroform Much will depend upon how much longer the surgeon requires to finish his operation If only a few minutes more are required, nothing is necessary but to cut down the amount of ether being given to the minimum possible If, however, the surgeon has still a good deal to do, the safest

thing is to withdraw the ether and substitute chloroform or a mixture Be it clearly understood however, that such a change over is not devoid of risk If it is to be made, it must be done early, before the patient is cyanosed and almost drowned in his own secretion The respiratory embarrassment with its resulting tendency to cyanosis is alleviated by oxygen It is useful in those cases to direct a gentle flow of the gas under the mask In a neglected case where cyanosis has already appeared, there will be no option but to interrupt the operation, empty the chest by encouraging coughing, and to aid the process by compressing the patient's chest during expiration Thereafter chloroform may be given, but with the greatest care, and with oxygen

*Gasping and sighing* are not common phenomena, but when they occur, call for close notice from the anæsthetist Excluding, of course, such occurrences in the first stage, before volitional control has been lost, they may be *usually but not invariably ascribed to overdosage or to the appearance of definite surgical shock* Whenever they are noticed, therefore, it behoves the administrator to overhaul the patient thoroughly, to consult the eye reflexes, the skin reflex and the pulse, and not to rest until he is assured that there are no other signals of danger to be found

*Stertor and stridor*—The first of these is caused by flapping of the soft palate It is a noise low in pitch, resembling ordinary snoring Indicating as it does that the palatal and therefore probably other muscles, are relaxed, it may, if moderate in volume, usually be taken as a favourable sign If it becomes very loud, however, the probability is that the base of the tongue has fallen back cyanosis will begin to appear, but will immediately be remedied by pulling forward the jaw or, in extreme cases, using the tongue forceps

*Stridor* is a high pitched sound produced by approximation of the vocal cords It has already been dealt with in Chapter III, as have also other forms of *obstructed respiration*

## FALSE ANÆSTHESIA

This term has been applied to a condition often seen in children, and occasionally in adults It is almost limited to chloroform, the author has never seen a genuine case when ether has been in use It appears very quickly after inhalation has begun, the muscles are relaxed, the respirations quiet and regular, the conjunctival reflex sluggish A very marked feature is the excessive smallness of the pupil Obviously, then, the condition much resembles a true third stage, but if the operation be begun the mistake will very rapidly be made evident, for the patient will at once move and cry out In essence, the condition is simply one of ordinary sleep It can be recognised by its appearance after a period of inhalation too brief for the induction of true anæsthesia by the very small pupils and the lightness of the respiration It will be a waste of time to permit the condition to continue, as the lightness of the respiration delays the taking in of a dose of the anæsthetic sufficient to induce a proper third stage The remedy is simple—rub the lips and face smartly with a towel or the hand when respiration will at once deepen and the pupil dilate Thereafter the induction should proceed normally

## CHAPTER VI

## PREPARATION OF THE PATIENT

For all but short anæsthesias conducted chiefly by nitrous oxide, the alimentary tract of the patient must receive careful preparation. In doing this, one must avoid excessive starvation and purgation, both of which tend to increase shock.

We will suppose that the operation is timed for 10 a.m. on Tuesday morning. On Monday morning the patient receives an aperient, which may be varied a little to suit his tastes and habits. If he has no preference, there is nothing better than an ounce of castor oil. During the rest of Monday he has a light diet: fish and milk pudding in the middle of the day, a little soup at night. The aperient should operate before 9 p.m. When that is over the patient retires to bed. During the day he may be allowed to move about his room a little, but should not undertake any exertion.

Realising the profound physiological effect of purgation, many surgeons would nowadays prefer to give the patient the aperient on the Monday night, while others have quite definitely abandoned purgation altogether.

If there be excessive nervousness or a natural tendency to insomnia, sulphonal gr. 15, veronal gr. 8, or nembutal gr. 1½ may be given early in the evening, to ensure a night's rest.

About 6 a.m. on Tuesday morning a large soap and water enema used to be given, and when this had operated,

a cup of tea or a little soup or Bovril was given There after nothing should be given by mouth Many surgeons now omit the morning enema, but the cup of tea is, of course, still given

The early forenoon is the time of choice for any operation, but if an afternoon time be of necessity chosen, the patient should not be starved throughout the forenoon A repetition of the early morning meal may be allowed about 11 a m

In cases such as gastro enterostomy, where the alimentary tract will be opened, the preparation must be a little more stringent It is usual to allow no solids at all the day before A saline enema may be given an hour or two before operation, when the soap and water has been evacuated

In Chapter XIX will be found some reference to the question of *acidosis* following operation under general anæsthesia Even apart from the clinical entity known as post operative acidosis or delayed chloroform poisoning, there is reason to believe that a very large number of cases show signs of a minor degree of acidosis and that some unfavourable sequelæ, particularly vomiting, if not actually due to acidosis (or rather diminished alkalinity of the blood) are at any rate closely associated with it For this reason many surgeons now give large doses of alkali (bicarbonate of soda) with sugar or dextrose, for two or three days before operation, and find the sickness rate in the wards much diminished For consideration of the theoretical aspect of this question, Appendix III (page 289) may also be consulted

There is reason to believe that sugar bears some special relation to the absorption of anæsthetics, especially ether Prof Exner of Vienna advocates the intravenous injection of a solution of glucose ten to twelve hours

before the operation and finds that difficult subjects such as alcoholics go under much more easily if this be done Even if we do not consider this special procedure necessary there would appear to be every reason why we should take pains to ensure that the patient goes to the table not suffering from sugar starvation

### PRELIMINARY HYPODERMIC MEDICATION

This great improvement in anæsthesia was practised many years ago by a few surgeons but it was only when open ether assumed its present position of pre-eminence that it was widely adopted Naturally even now there is not complete unanimity as to drugs and dosage but the following may be taken as a fair resume of the average modern views

#### SULPHATE OF ATROPINE

There can at any rate be no question that this drug should be given no matter what the inhalational anæsthetic which is to follow it (although M Kesson deprecates its use before gas-oxygen anæsthesia and it is certainly less called for in this case than before other anæsthetics) nor what the type of patient A suitable dose for an adult is $\frac{1}{150}$ gr to $\frac{1}{100}$ gr somewhat reduced for young persons Even infants however tolerate the drug well and may be given $\frac{1}{400}$ gr The principal advantage is the drying up of the secretions of saliva and mucus from the respiratory mucous membranes an action of very great importance if ether is to be the anæsthetic Another advantage which has been claimed is the paralysing action of atropine on the vagus nerve endings in the heart and bronchioles and thus the lessening of the danger of syncope although it is doubtful how far this is

valid There is no doubt, however, of the immense benefit accruing from a preliminary dose of this drug in controlling inconvenient secretions during ether anæsthesia It should be given about one hour before the commencement of the administration

## Narcotics

Drugs of the morphia class present very definite advantages as adjuvants to ether or gas oxygen Before the operation they serve to calm the patient during its progress we find much less mucus secreted and a certain reduction in the amounts of the inhalational anæsthetic required, and as a natural corollary there is during the convalescence stage, less after sickness and less tendency to respiratory reactions, such as bronchitis If this were all the story there would be complete unanimity as to the use of morphia or one of its substitutes before operation There is, however, another side to the picture Morphia acts as a depressant to the respiratory centre, and if this effect is really marked, it involves a slow intake of the inhalational anæsthetic and a correspondingly slow induction In extreme cases we have a patient cyanosed before he is fully under, and the muscles, particularly those of the abdominal wall, will be rigid and troublesome to the surgeon This most undesirable picture is particularly prone to present itself if morphia is used before chloroform, or any combination of which chloroform constitutes a material proportion, and we have no hesitation in saying definitely that morphia should not be used before chloroform, save under the most exceptional circumstances and in very specially skilled hands As a preliminary, however, to ether or gas oxygen, morphia is habitually used by many anæsthetists Indeed, if gas

oxygen is to be relied on as the mainstay for a major operation involving complete surgical anæsthesia, a dose of morphia may be regarded as quite essential It is well not to give it more *than half* an hour before operation, and the dose must be small—a sixth of a grain for adults and less for young persons For children under the age of twelve it is more likely to do harm than good, and should not be given In every case it should be combined with atropine

A drug which has been used to a considerable extent with morphia is Hyoscine hydrobromide It may be given to adults in doses from $\frac{1}{150}$ to $\frac{1}{75}$ of a grain Probably because of the powerful depressant action on the respiratory centre this combination has lost some of its one time popularity As a preliminary to gas-oxygen anæsthesia, however, and especially in muscular patients and alcoholics it is of value Omnopon $\frac{1}{6}$ to $\frac{1}{3}$ gr, or Heroin hydrochloride $\frac{1}{12}$ gr, have also had their advocates

## CHAPTER VII

## BASAL NARCOTICS

SINCE the discovery of the narcotic effects of Avertin, Paraldehyde, and the derivatives of Barbituric Acid the scope of pre-medication has been considerably extended, and with certain of their number the field of general anæsthesia has even been invaded With the exception of paraldehyde, a liquid, they are all solid substances, and are administered by mouth, or, in solution, by rectal or intravenous injection Where they are used merely as basal narcotics their action results in the production of sleep varying in profundity with the drug employed and the dosage For this reason they have been widely used to mitigate the apprehension to which operation and anæsthetic give rise Knowledge of their action has spread, and it is now not uncommon to be asked by a patient to be put to sleep in bed, by their means and to be spared the anxiety and nervousness associated with a visit to the operating theatre in a state of full consciousness

It must be remembered that all the drugs in this group, from their physical properties, are less controllable than are the inhalational anæsthetics Once administered the action must run its course For this reason the dose must be fixed within limits which will be most unlikely to interfere with vital processes, and is rarely adequate to produce an anæsthesia sufficiently profound in itself They have usually, therefore, to be supplemented by some other anæsthetic

In describing the various drugs which are employed as basal narcotics those of the barbiturate group will be limited to the two now most frequently employed—nembutal and sodium evipan It would be impossible within the scope of this book to deal adequately with all the other barbiturate derivatives which have been used

## AVERTIN (Tribromethyl Alcohol ($CBr_3CH_2OH$))

Avertin is a white crystalline powder, not readily soluble in water It is supplied in solution in amylene hydrate a clear fluid 1 c c of which contains 1 grm of avertin

### ADMINISTRATION

The choice of routes lies between the intravenous and the rectal but as avertin is very rapidly detoxicated the former is not used the resulting period of narcosis being too brief It is therefore used as a rectal injection made up in 2½ per cent strength in distilled water

In preparation the rectum should be washed out about twelve hours before the dose is to be given The diluted avertin solution must be tested with Congo Red immediately before use A few drops of this added to 5 c c of the solution ought not to change colour The solution is not very stable hydrobromic acid being liable to appear its presence indicated by the colour changing to blue In this event the solution must not be used as it then possesses a highly irritant action on the mucous membrane of the bowel Provided it is not overheated, however and not exposed to light no decomposition is likely to happen within three or four days

The patient lies in bed on his left side and the avertin solution warmed to about 35° C (a temperature over

40° C is liable to produce decomposition) is slowly run into the rectum through a funnel connected with a soft rubber catheter, size 14 French The injection should take about ten minutes, and should be completed twenty minutes before operation time

*Dosage*—This is regulated according to the patient's weight For each kilogram of body weight 1 c c of avertin may be given Thus for a patient weighing ten stones 6 3 c c of avertin is the dose, and when made up with 2½ per cent distilled water the total quantity of dilute solution is 254 c c

### Action

Absorption of avertin from the bowel is rapid and its sedative action is soon evident Within a few minutes the patient becomes drowsy and usually within fifteen minutes passes quietly into a deep sleep Ordinary auditory and ocular stimuli produce no response, but, as a general rule, painful stimuli, *e g* incising the skin, elicit subconscious reflex response in the form of muscular twitching or rigidity Very occasionally instead of this quietly induced sleep an excitement stage of varying duration and severity occurs No satisfactory explanation of this has been offered and it does not seem to be more common in alcoholics, who, as a rule, make good subjects for avertin The deep narcotic action continues for from three quarters of an hour to an hour and a half, although drowsiness continues for some time after this, for three or four hours Shipway and Blomfield conclude that it takes about forty-five minutes for the whole dose to be absorbed from the bowel During the narcosis there is a slight fall in blood pressure, amounting to about 10 mm The patient's colour remains about normal provided no interference with respiration is permitted

In this connection it must be remembered that respiratory obstruction, caused by the jaw falling back is to be expected and prevented Not only during the operation period but for some time thereafter the jaw must be kept forward There is usually some respiratory depression with a quiet rather shallow type of breathing The pupil is contracted and active, and the corneal reflex present The depth of anæsthesia varies It is unsafe to administer avertin in doses sufficient to produce full anæsthesia With the dose indicated above there is occasionally developed anæsthesia of a depth sufficient for the performance of minor operations, or any operations not necessitating muscular relaxation But in most cases the action has to be supplemented either with gas oxygen or ether

*Avertin is detoxicated in the liver and excreted by the kidneys* Occasionally a toxic action on liver and kidneys, similar to that associated with chloroform poisoning, is produced

## The Use of Avertin

Shipway and Blomfield (*Lancet* March 16th 1929), gave the following groups as those in which avertin has especial value — (*a*) for patients who dread the anæsthetic, or have suffered after former anæsthetics, (*b*) for the subjects of exophthalmic goitre or others in whom the psychic aspect of the matter is of real import (*c*) for patients who have to undergo long operations not requiring very deep anæsthesia *e g* long operations on bones plastic operations laryngectomies (*d*) for injections for tri geminal neuralgia (*e*) for patients who suffer from any pulmonary complaint and (*f*) in prolonged operations about the head and neck

It is contraindicated in operations on the rectum in

operations where depression of the respiratory centre and reflexes, and of the blood pressure are undesirable and in patients the subject of renal or hepatic disease

### After-effects

As regards the ordinary complications liable to follow anæsthesia, sickness and respiratory complaints much may be said in favour of avertin Cases have been recorded of prolonged unconsciousness following its use, and even in normal cases additional watchfulness is required until the patient s control returns

### Safety

Reliable figures are difficult to obtain A number of deaths have been recorded and attributed to avertin Lundy has assessed the death rate at 1 in 3333 (Staff Meetings of the Mayo Clinic 1929)

## PARALDEHYDE ($C_6H_{12}O_3$)

Paraldehyde is the safest of the basal narcotics Probably for this reason it has acquired a special popularity for administration to children It has no depressant action on respiration or blood pressure Against those advantages there have to be considered its disagreeable odour and uncertainty of action excitement being more liable to follow its administration than any of the other basal narcotics

*Dosage* —It is safe to calculate this on the basis of one drachm per stone of body weight, and to administer in 10 per cent dilution in normal saline Like avertin it is given per rectum and the same technique followed The *injection should be given thirty minutes before operation* time

**NEMBUTAL (Sodium Ethyl Methyl Butyl Barbiturate)**

Nembutal is probably the most widely used of the basal narcotics It is a white crystalline substance and is stable As it may be given by mouth it is therefore more convenient than the other basal narcotics mentioned It may also be given intravenously It acts very well in combination with morphia

*Dosage*—Given orally the dose is from $\frac{1}{2}$ grain in children under four years of age up to 6 grains The usual dose for a normal adult is 3 grains Owing to its bitter taste it is given in capsules, which may be obtained in $\frac{1}{2}$ grain and $1\frac{1}{2}$ grain doses A common practice with a normal adult is to give a $1\frac{1}{2}$-grain capsule the night before operation and 3 grains with or without $\frac{1}{6}$ grain of morphia, half an hour before operation As its action is interfered with in the presence of highly acid stomach contents, it is an advantage to precede the dose of nembutal with a drachm of bicarbonate of soda

As might be expected from an oral administration, the action is to some extent uncertain With some patients sleep is rapidly induced while with others a mild amnesia is the result In nearly all cases, especially if a combined dose of morphia is given, a pleasurable care-free frame of mind is produced and the patient put into a state well adapted to the taking of a general anæsthetic Nembutal given in this way makes a good prenarcotic for gas-oxygen, spinal or local anæsthesia

### Intravenous Administration

Nembutal is given in a 5 per cent solution in distilled water A 10 c c syringe is used for the purpose, and the fluid run slowly into a vein at the rate of 1 c c per minute

The dose is best judged by asking the patient to count or engaging him in conversation Immediately the patient ceases to count, or to respond, the injection is stopped An average dose is 5 grains, and $7\frac{1}{2}$ grains is the maximum

A slight fall in blood pressure accompanies the administration and there is also depression of the respiratory centre Fatalities have been rare and associated with failure of respiration Experimentally in animals overdosage is frequently followed by œdema of the lungs and broncho pneumonia

**SODIUM "EVIPAN" (Sodium N. Methylcyclohexenyl Methyl Barbiturate)**

A white crystalline powder readily soluble in water It is given in 10 per cent solution and supplied by the makers in boxes of five ampoules containing 1 gramme of sodium evipan and five ampoules containing 10 c c of distilled water One ampoule of each is opened the sodium evipan dissolved in the distilled water and the solution ready for use is drawn into a 10 c c syringe This is injected slowly into a vein at the rate of about $2\frac{1}{2}$ c c per minute The patient is carefully watched and the point is noted at which response to question ceases After this as much of the solution as has already been given is injected by which time narcosis is established The depth and duration of narcosis is very variable In some cases the patient will submit to an operation lasting thirty minutes In others any operative measures result in inconvenient reflex response almost immediately It is rarely possible to count on any degree of muscular relaxation Some anæsthetists recommend the employment of larger doses in order to prolong and deepen the anæsthesia, but, as several fatalities have been reported

even within the limits of a gramme dose, this is open to serious objection

Sodium evipan has proved of most value in minor operations, especially where for some reason a respired anæsthetic is undesirable It has been recommended for use in dentistry, but it must be remembered that, if used for this purpose, great care must be taken, as with all basal narcotics, to preserve an open airway. The dangers which accompany its administration are greatly increased in the presence of anoxæmia

It is perhaps not strictly accurate to include sodium evipan in the group of basal narcotics as it has been extensively used as the sole anæsthetic in minor cases At the same time its action closely resembles that of the basal narcotics, and, for operations of any magnitude, has to be supplemented by some other anæsthetic.

## CHAPTER VIII

## NITROUS OXIDE

### SPECIAL PHYSIOLOGY

Upon the nervous system, nitrous oxide acts like other anæsthetics, but the stages of anæsthesia are passed through so rapidly that their differentiation is difficult It is rare for struggling or excitement to be manifest, unless air or oxygen be admitted at the same time, when the effect which led Humphry Davy more than a century ago to apply to nitrous oxide the name of "laughing gas" is very evident indeed

Upon the other systems of the body, nitrous oxide has little if any effect in itself The essential point to remember in connection with nitrous oxide administered unmixed with air or oxygen is that there is an *inevitable element of anoxæmia* The larger part of the oxygen normally carried by the red blood corpuscles is eliminated and replaced by $N_2O$, oxygen starvation is therefore of necessity present In other words, the "vicious circle of asphyxia" (*see* Fig 4) is entered, and muscular spasm is bound ultimately to appear Moreover, the blood-pressure rises very materially as a result of the lack of oxygen That no harm results to the normal healthy patient from this rise is due to the fact that the gas does not in itself poison the heart muscle, which can therefore stand up to the extra strain of working against higher resistance, so long as the process is not carried to extremes

## APPARATUS

Nitrous oxide is supplied by the makers as a fluid condensed in steel bottles or cylinders and only becomes gaseous upon being released from them In passing from the fluid to the gaseous state heat is of course lost, and it will be noticed that the end of the cylinder which is in use becomes rapidly crusted over with frost Special

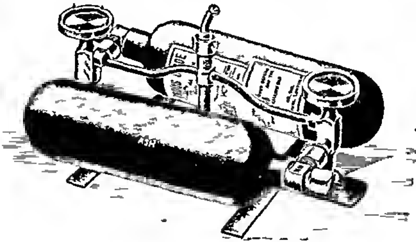


FIG 1 —Frame for adapting vertical cylinders to foot use

precautions are now taken by the makers to supply dry gas i e gas treated in such a way as to be free of water vapour The troublesome freezing that used to occur at the valve outlet of the cylinder has thus to a large extent been abolished *

The cylinders are of various sizes and designated after the number of gallons of gas which they will supply 25 is

* Full cylinders must not be left in direct sunlight for any prolonged period During a heat wave in July 1923 omission of this precaution caused an explosion in a London operating theatre

the smallest size, 50 or 100 are more usual, anything up to 500 is occasionally met with in hospital practice. Moreover the cylinders are of two types, called respectively *vertical* (for use in the upright position), and *angle* for use in the horizontal position (*see* Fig. 13)

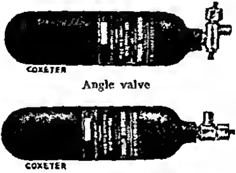



Fig. 13.—Two types of nitrous oxide cylinders

The cylinders are fixed in frames of various types of which examples are seen in Figs. 12 and 15.

Upon each cylinder, of whatever size or type, will

Fig. 14.—London Hospital Foot-Key (*Coxeter*)

be found a label stating its weight when full and empty, the difference representing the weight of the contents when the bottle is full. For instance, in the case of the 50 gallon cylinder the weight of its full charge is 15 ounces. *Weighing the cylinder is the only certain means which* we have to estimate how much of the charge remains

The student will readily appreciate, therefore, that once a cylinder has been used at all there is always a risk of the supply of gas from it running out during an administration It is for this reason that cylinders are habitually used in couples, one of which is always supposed to be quite full To this one it is well to attach a label marked "full," and care must be taken to replace at once a cylinder known to be empty In this way we always have upon the frame one cylinder partly and another entirely full

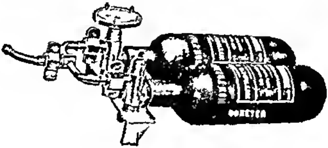


FIG 15 —Two cylinders on stand

By whatever makers the cylinder is supplied, it will be found that the thread upon the outlet pipe is the same,* and the metal nipple figured in Fig 15 will fit it To the distal end of the nipple a rubber tube is attached which leads to a rubber bag, usually of 2 gallons capacity

The remainder of the apparatus may be of several types

Fig 17 shows the ordinary *Barth three way* tap with facepiece the indicator on the tap has three possible positions designated on the dial as "Air," "Valves" and "No Valves" If the tap is pointed backwards towards the bag at the position marked "Air," the end of the bag is closed and the patient is breathing air only With the tap in the middle position of "Valves," the inspiration

* This does not apply to American cylinders

of the patient will draw gas from the bag, but the expiration closes the valve which is now in operation at


FIG 16.—Complete $N_2O$ apparatus showing twin cylinders supply pipe 2 gallon bag three way tap and facepiece

*the orifice of the bag, and will open the expiratory valve* which conducts the expired air into the general atmosphere

In the third position of "No valves" the patient breathes both into and out of the bag

Fig 18 shows the Hewitt type of valves The calibre of the orifices through which respiration takes place is greater than in the Barth three way tap, and to that extent this type of valve is to be preferred Although differently arranged, exactly the same possibilities are present in it

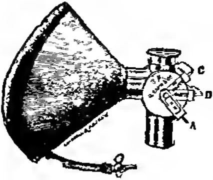


Fig 17 —Barth three way $N_2O$ tap

The *facepiece* is sometimes made of celluloid with an inflatable rubber edging The object of this type of facepiece is that the colour of the lips may be appreciated by the anæsthetist during the administration The preferable plan is to make the whole facepiece of rubber, with an inflatable border Such a facepiece made by a good maker will last many years, and is much more stable and reliable than its celluloid competitor

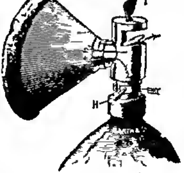


Fig 18 —Hewitt s wide-bore gas valves

### THE CARE OF THE NITROUS OXIDE APPARATUS

This is a matter of considerable moment, particularly to those who do not use their apparatus every day After use, the valves facepiece, and bag should be disconnected

from each other, all moisture wiped away from the bright parts, and the bag hung up with its open end downwards, and preferably in a warm room If re breathing has been extensively practised it is well to wash the bag out with some carbolic lotion before hanging it up The rubber valves in the valvepiece are liable to lose their elasticity, particularly if kept in a cool place after becoming damp From time to time the valve piece should be taken to pieces, the valves carefully dried in front of a warm fire and powdered over with a little talc

## ADMINISTRATION

As nitrous oxide is commonly administered for a minor operation the patient is often fully clothed, for dental extractions the sitting position is adopted Care should be taken that the respiration shall not be obstructed by tight clothing round the throat or chest, and that the head and neck are neither unduly flexed nor extended upon the shoulders The patient should not have any solid food for two hours before the anæsthetic At the last moment he should be instructed to empty his bladder Artificial dentures, if present, should be removed, and, if the anæsthetic is being given for the purpose of the extraction of a tooth, it will be necessary before applying the face-piece to insert between the teeth a dental prop (*see* Fig 5) Standing to the left and slightly behind the patient the anæsthetist's first step is to secure a good apposition between facepiece and face This is best done by working from above downwards, that is to say, secure first a good fit at the bridge of the nose and then approximate the remainder of the rim of the facepiece to the cheeks and lower jaw During this stage the indicator of the tap is kept at "Air"

Working with the left foot the administrator now opens the head of one of the cylinders with the foot key It is wise first to have loosened this with a hand key and leave it just on the swing Gas is allowed to flow into the bag until it is partially but by no means tightly distended The patient is instructed to breathe naturally and easily and during the whole process the anæsthetist should converse with him in a quiet easy way The tap is now turned to Valves and the patient begins to inspire the gas a supply of which is allowed to flow steadily from cylinder into bag After a few breaths of the gas when the sensibilities of the patient are a little dulled it is wise to allow the gas to flow a little more freely and to distend the bag This exercises upon the patient a slight *positive pressure* which has been proved both experimentally and practically to increase the rapidity of the absorption

The valves are left in operation for some thirty or forty seconds after which time the supply of gas should be cut off and the tap be pushed over to the position of No valves for further twenty seconds This should be ample to secure full gas anæsthesia

*The phenomena* seen in nitrous oxide anæsthesia are so different from those in any other that a few words must be said about them Within a few seconds of the inhalation beginning the colour of the patient shows evidence of the presence of the gas in his blood The normal complexion changes first to a dull pink and very rapidly to the definite blue of cyanosis The *eye symptoms* are of the utmost value Very early the pupil begins to dilate and the eyeball tends during the first twenty or thirty seconds to rotate as if the patient were looking for some object in his field of vision In full anæsthesia the eyeball however comes to rest usually pointed downwards The pupil is widely dilated the conjunctival

reflex is almost or even entirely abolished, but the corneal reflex is still brisk *The respiration* tends to become steadily deeper and more frequent, and in the later stages stertor at least, if not stridor, usually develops *The muscles* under ordinary nitrous oxide anæsthesia are rarely entirely relaxed, but the limbs hang motionless, and it is only if an attempt be made to move them into some abnormal position that one appreciates the persistence of muscular tone

A phenomenon peculiar to nitrous oxide anæsthesia is observed in its deepest stage Designated as *jactitation*, it consists in a spasmodic twitching beginning in the limbs but spreading from them to the trunk if its development is allowed to proceed It commences as a clonic spasm but tends if allowed to persist, to pass into a state of tonic spasm Jactitation is almost wholly a phenomenon of anoxæmia, and is therefore definitely an indication that the process of oxygen starvation has been carried as far as is permissible

*The signs of fully developed nitrous oxide anæsthesia*, then, are —

(a) Deep, regular snoring respirations

(b) Dilated pupils

(c) Rotation of the eyeball downwards

(d) Loss of conjunctival but persistence of corneal reflex

(e) A colour of the skin definitely blue but not blackish blue

(f) The commencement of jactitations

*The signs of overdose are* —

(a) An enormously dilated pupil not reacting to light

(b) Loss of corneal reflex

(c) A blackish blue colour
(d) Jactitations fully developed ending in tonic spasm
(e) Failing respirations

The final arrest of respiration in nitrous oxide anæsthesia is usually painfully sudden Upon the respiratory side the only warning is one or two gasps and even that is sometimes absent The paralysed pupil and the jactitations are the most useful signs of overdose

The above then may be taken as an account of what one expects to see in a normal gas anæsthesia during the induction stage For the great majority of cases nitrous oxide is given for the purpose of rendering painless the extraction of a tooth and it is in this large class of case the induction stage only which need be considered It requires only some fifty to sixty seconds to bring the patient to the stage described under the heading fully developed anæsthesia and when that has been attained the mask may be removed and the operation begun From the moment of removal of the mask however it must be noted that the patient begins to breathe fresh air and to eliminate the $N_2O$ The period of anæsthesia available to the surgeon or dentist during which he must perform the operation is therefore very small In thirty seconds the patient has frequently recovered sufficiently to begin to feel pain and it is rare to secure more than forty five or fifty seconds by the use of a single dose of nitrous oxide

## NITROUS OXIDE AND AIR

If the nature of the operation does not necessitate the removal of the mask from the face it is possible to maintain nitrous oxide anæsthesia for some considerable time The exact length of that time varies a good deal with two

factors—the type of patient and the experience of the administrator Heavily built muscular patients are not easily dealt with by prolonged gas anæsthesia (unless with admixture of oxygen, as explained in Chapter IX) Of far greater importance, however, is the other factor The student can easily be taught to give a single dose of gas for the extraction of a tooth, or the momentary incision of an abscess He will, however, be wise to secure a good deal of practice in that class of work before attempting to prolong gas anæsthesia for more than a minute or two

With reasonable skill and experience and the utmost care, it is, however, perfectly possible to prolong nitrous oxide anæsthesia for periods of five ten or even fifteen minutes in the average healthy patient As soon as the signs of full anæsthesia appear, the valve tap is pushed back to "Air" for the space of one inspiration and one expiration, and then at once pushed back to "No valves" By this manœuvre one inspiration of air is permitted to the patient, whose colour at once shows amelioration, or at any rate no further progression of cyanosis The admission of air is repeated every third, fourth, or at most fifth respiration After the first minute or so of this cycle of events it is obvious that the contents of the bag will be composed of a mixture of nitrous oxide air, and $CO_2$ in proportions quite impossible to calculate It is therefore best to push the indicator to "Valves, and allow the bag to be emptied by the suction of the patient's inspirations The cylinder head is then opened by the turning of the foot key, and the bag filled again with gas The cycle of "Air" and "No valves" is then begun again for another minute or so

It must be understood that by this process it is not to be expected that an ideal anæsthesia can be produced

Some movement of the patient will not improbably take place when sensitive structures are cut or handled by the surgeon, and at no time will the muscles be entirely relaxed Such an anæsthesia is therefore only suitable for a limited class of case, but does admirably for, say, opening an abscess, exploring its interior, and removing from it a sequestrum or an easily found foreign body, and for many of the other operations of minor surgery

## CONTRA-INDICATIONS TO THE USE OF PURE NITROUS OXIDE GAS

In the healthy subject there is no safer anæsthetic than nitrous oxide when administered properly and limited to its proper province

From the account given of the physiological action of the gas it will, however, be obvious to the student that in a limited class of case its use is not permissible Such cases fall into two categories

*Firstly cases in which an asphyxial element already exists will have their condition greatly aggravated by the substitution of $N_2O$ for the oxygen in their blood* —Already caught in the vicious circle of asphyxia, nitrous oxide would but push them deeper into the vortex Examples of such cases are patients suffering from tumours or inflammatory swellings in the neck which are pressing upon the air passages In passing, one may note that it might be the desire of the surgeon to submit an individual case falling into this group to the operation of tracheotomy for the immediate relief of the condition The short space of time required for this little operation might well tempt the unwary to choose nitrous oxide as the anæsthetic and in point of fact such an error of judgment has more than once been made with fatal results

*Secondly, no patient suffering from any condition which will be aggravated by a sudden rise of blood-pressure, should be submitted to nitrous oxide undiluted by oxygen* —Examples of such conditions are cases of *dilated right heart* with weakened cardiac musculature

Such hearts could not be expected to work against a peripheral resistance suddenly raised, say, from 120 mm of Hg to 180 or even 200 mm—figures well within the possible in deep gas anæsthesia Similarly, so great an increase of pressure would be dangerous to a patient suffering from an *aneurysm*, or from *extensive arterio sclerosis* with high blood pressure

It will be noted that the above warnings are limited to the use of pure nitrous oxide, that is, $N_2O$ unmixed with oxygen The extent to which the dangers referred to can be met by the admixture of oxygen in the manner to be described in the next chapter is largely a matter of the skill and experience of the administrator

## NASAL METHODS

The object of using this route is the continuance of the administration throughout the period in which the dentist is doing his work The essentials of a suitable apparatus are —

(*a*) A nosepiece fitted with an expiratory valve, which can be closely adapted to the nose, and of as small a size as is compatible with efficiency

(*b*) Two supply pipes from bag to nosepiece

(Either in (*a*) or (*b*) an air valve allowing admittance of air when required )

(*c*) A mouthpiece with expiratory valve

(*d*) A supply pipe from bag to mouthpiece, fitted with

stop cock, by which gas to mouthpiece may be admitted and cut off at will

(e) A two gallon rubber bag, over which is fitted some form of rigid framework, either in the shape of a fishing-net, string-bag or metal bands

(f) A supply of gas

After the insertion of a dental prop, preferably placed well to one side of the mouth, the patient is instructed to breathe through the nose, and the nosepiece is fitted in position with the air valve open On the completion of two or three breaths during which the bag is filled with gas, the air valve is closed and the patient is inspiring from the bag and expiring through the expiratory valve into the atmosphere In those patients with a good nasal air way, who co operate well by breathing entirely through the nose, it is possible to conduct the whole anæsthesia without using the mouthpiece at all This, however, is not always possible After a few breaths with the nosepiece in position, it will be obvious whether or not the mouthpiece is to be required If the breathing be not entirely nasal the mouthpiece is fitted over the mouth and the stop-cock opened, admitting a flow of gas to it, so that gas is now being delivered both by nose and mouth When anæsthesia is fully developed, and the signs are the same as those already described for gas anæsthesia, the supply of gas to the mouthpiece is cut off and the mouthpiece dropped At the same time the expiratory valve in the nosepiece is closed, so that re-breathing is established through the nose The gas is now supplied under increased pressure by distending the rubber bag against its rigid container A gauze mouth pack is now of great service It should be placed well back in the mouth against the palate The primary

object of this is to prevent the ingress of air by the mouth which, if not checked, may completely spoil a nasal

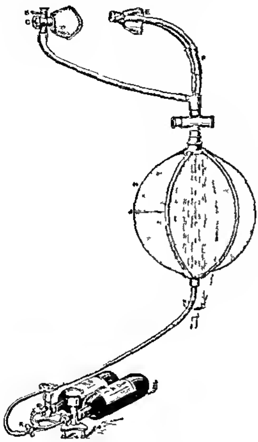


FIG 19 —Coleman s aseptic nasal inhaler (Ash s No 4)

The figure shows the gas bag (H) within the compressor frame (J) Above the bag is the special device for admitting air to the desired degree Two tubes held together by a sliding clamp (F) pass round the patient s head and convey the gas to the nosepiece (E) A side tube leads to the mouthpiece, with its regulating tap (B) to cut off supply of *gas when not required, and its expiratory valve (C) The shaded lines* show the compressor frame closed for transport

anæsthesia. It also serves admirably in preventing blood or a fragment of tooth from going back and causing laryngeal obstruction

Those numerous actions seem very complicated, but, in reality, with a little practice they can be carried out in a few seconds When they have been completed the patient is ready for operation, the anæsthetist's attention being now directed to the accurate fitting of the nosepiece, the continued delivery of gas through it under slightly increased pressure, and the allowance of sufficient air through the air valve to prevent asphyxia For dental work this method is of enormous advantage, and suffices for the majority of extraction cases It is also useful for anæsthesia in other oral operations.

Fig 19 shows Coleman's Aseptic Nasal Inhaler as made by Messrs Claudius Ash It has the advantages of being practically self-retaining when once fixed to the patient's face, and of being capable of sterilisation. The designer has largely overcome the difficult problem of admitting atmospheric air to the patient while still maintaining some pressure in the supply of nitrous oxide gas.

Nasal attachments are provided with most of the gas-oxygen apparatuses mentioned in the next chapter. With them good results can be obtained with comparative ease.

For a more detailed account of nasal methods, the student is referred to works devoted entirely to Dental Anæsthesia, such as Luke and Ross's *Anæsthesia in Dental Surgery* (Wm Heinemann)

## CHAPTER IX

### NITROUS OXIDE AND OXYGEN

THE account given in the previous chapter of anæsthesia by nitrous oxide and air will have convinced the student that it is a somewhat inelegant method with a limited sphere of usefulness The reason is obvious In atmospheric air, oxygen exists only in the proportion of about one to four of nitrogen To sustain life it is therefore necessary to admit to the anæsthetic mixture an amount of air which leaves too little room for the anæsthetic factor—nitrous oxide If, however pure oxygen be used, the nitrous oxide is diluted to a much less degree, and far better results are obtained

The exact scope for gas oxygen anæsthesia cannot at present be defined with certainty The work of Crile and the experience of the War have done much to enlarge it We may say that the following are definite indications for its use —

(*a*) Minor operations lasting five to fifteen minutes, particularly if performed on out-patients

(*b*) Operations of any variety upon the subjects of severe shock

(*c*) Operations upon patients suffering from acute sepsis

(*d*) Operations repeated upon the same subject at short intervals

(*e*) Other operations which do not demand a great degree of muscular relaxation, and for which the patients desire the advantages of the method, provided no contra indication, such as alcoholism or excessive muscularity, is

present In hospital practice, the added cost of the method must be taken into consideration, and the use of the method limited to those patients whose condition definitely demands it

As regards (*c*) and (*d*), the lack of toxic properties in nitrous oxide gas, and the rapidity with which it is eliminated, give it a tremendous advantage over ether or chloroform To men with shattered bones and extensive damage to soft tissues, badly infected with sepsis, who required repeated opening up of pockets, changing of gauze packs, etc , the advantage of gas-oxygen over ether was evident, and was easily appreciated by the patients themselves during the late War Even in normal subjects the after sickness and malaise are definitely less with gas oxygen than with other anæsthetics

There are, however, certain *drawbacks* to the method which must be appreciated —

(*a*) The necessary plant is heavy, bulky, and costly, it cannot be easily transported

(*b*) The running cost is high as compared with ether or chloroform

(*c*) It has been said by some that gas-oxygen can only be given by an expert That is a statement too extreme, in our opinion Certainly, of all anæsthetics it is the most difficult to give successfully Adequate study and proper teaching by an expert are required, but given these two helps, anyone can soon learn to administer gas-oxygen for minor surgery Considerable experience is, however, necessary before the beginner should give it for an abdominal section

**APPARATUS**

A good gas-oxygen apparatus is necessarily rather complicated The machines in the market are numerous,

and of the most diverse external appearance Certain broad principles, however, underlie all the machines, and it is to be hoped that some one of them will before long become practically the standard Once that is effected, hospitals and nursing homes could be expected to provide it So long as every anæsthetist asks for a different machine, they certainly will never do so A good machine must provide means for the following —

(a) *An even flow* of both gases under perfect control

(b) *A percentage of oxygen* in the mixture rising at the will of the administrator from 2 to 15 or 20 A safeguard provided on some machines is a side lead from the oxygen supply direct to the facepiece whereby pure oxygen can be given if required To meet this requirement it is not necessary that any indicator should be provided which shows with mathematical precision what percentage of oxygen is being given The colour of the patient tells us at once if too much or too little oxygen is being supplied, and all we need in the apparatus is some mechanism whereby we can tell approximately to what extent we are increasing or decreasing the percentage

(c) *Positive Pressure*—If the pressure at which the gases are supplied to the patient can be raised a little above that of the ordinary atmosphere, absorption is increased, and a deeper anæsthesia produced In the authors' view this is an essential point in a good instrument

(d) *Re breathing*—To supply the whole volume of gases required for inspiration during a long operation is costly and quite unnecessary Yet that is what is being done if the whole administration is conducted upon the "valvular" principle Moreover, a prolonged inhalation upon the valves tends to remove a great deal of $CO_2$ from the patient's blood and tissues (*see* Chapter IV) Periods

of partial or complete re-breathing do much to deepen respiration, and reduce the cost of the anæsthetic

(*e*) *Warming the Gases*—While not essential, this is certainly an advantage

(*f*) *Addition of Ether Vapour to the Mixture*—Gas-oxygen even well given is hardly capable of reducing to quiescence very robust people, unless the oxygen percentage is kept to an undesirably low level The merest trace of ether vapour as an adjunct is a great assistance during the stages of the operation where very sensitive structures such as the parietal peritoneum are being handled The more experienced the anæsthetist, the less will he require such assistance Most of the gas oxygen machines are now equipped with an ether container which is capable of supplying enough ether vapour to produce full ether anæsthesia Some have also a chloroform container

## HEWITT S APPARATUS

In this country the administration of gas oxygen was introduced by Hewitt and for many years his apparatus held the field Even now within a certain limited range, *i e* confining its use to minor operations, it has a place, and possesses the great advantage of being much lighter and less bulky than those more recently introduced It labours however under several limitations, the principal ones being that no facilities are provided for re-breathing and for the use of positive pressure Whilst those obstacles are not insuperable and might have been overcome had the inventor lived to develop the apparatus advances have been made in other directions and other methods have largely superseded Hewitt s For those we are largely indebted to American anæsthetists, who were pioneers in extending the scope of gas oxygen Of those Teter was

the earliest, and his apparatus made possible the use of re breathing, positive pressure, and the addition of ether vapour to the gases The gas-oxygen outfits in use to-day, of which there are many, may be regarded as descendants of Teter's, some in the direct line, of which McKesson's is a well-known example, and some by a collateral line, which Gwathmey originated by the introduction of a sight feed, and of which, in this country, Boyle's may be taken as a type It will be sufficient if descriptions of those two types, Boyle s and McKesson's, are given, as most other apparatuses differ only in points of detail

## BOYLE'S APPARATUS

This is made in two sizes, one for hospital use adapted for two 250 gallon cylinders of nitrous oxide and two 60-gallon cylinders of oxygen , the other more portable and suited for private use, fitted for two 100 gallon cylinders of nitrous oxide and two 30 gallon cylinders of oxygen In other respects the essentials of the apparatus are identical All cylinders are fitted with fine adjustment pressure outlets which allow of even control of the outflow of gases One cylinder of nitrous oxide and one of oxygen are connected by rubber tubing to the sight-feed bottle, the other two cylinders being reserves The sight-feed bottle is fitted with a metal topped stopper, perforated by three tubes, two inlet and one outlet The inlet tubes are continued almost to the bottom of the bottle, which is about three-quarters filled with water, by metal extensions, these being perforated along one side with four holes, each at intervals of about an inch, the lower ends of the tubes open When the gases are turned on at the cylinders the pressure may be so controlled as to allow them to emerge from one, two, three, or four

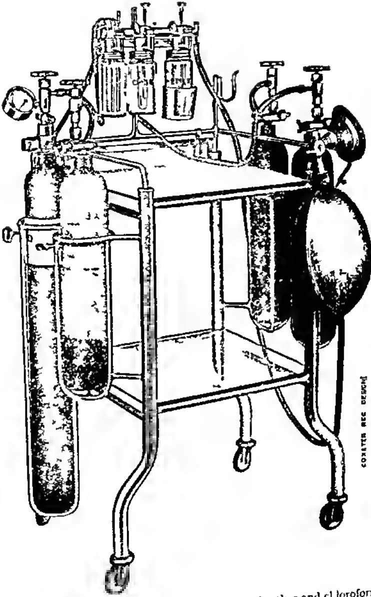



Fig 20 —Boyle's gas-oxygen apparatus with ether and chloroform bottles and intratracheal attachment (Coxeter)

holes, or from all four holes and from the open end of the tubes as well As they bubble through the water the relative proportions of the two gases may be seen and readily controlled to the desired mixture Usually at the commencement of an administration nitrous oxide is given alone, emerging from all four holes and from the end of the tube As anæsthesia develops, oxygen is gradually added in sufficient quantity to prevent asphyxia No rule of thumb method is possible in regulating the mixture, but generally an anæsthesia will be conducted with nitrous oxide bubbling from four holes, oxygen from one The outlet tube from the sight feed has a metal extension leading to another metal topped stopper, fitted to an ether bottle By means of a control lever the gases may be led through the ether in the bottle, or may be by passed without coming in contact with the ether at all From this stopper the gases are led by rubber tubing to a 2 gallon rubber bag The bag is fitted with a Barth three way tap and rubber padded facepiece, similar to those described for use with ordinary nitrous oxide administration, and permitting of re breathing or valve action

The sight-feed machine shown in Fig 20 is made by Messrs Coxeter and is to be regarded as their development of the Boyle type of apparatus It is well and neatly constructed and has a particularly well designed arrangement at the head of the ether bottle, by means of which the stream of gas can be directed in or out of the bottle very gradually The resulting delicacy with which the strength of ether can be regulated is a real advantage The older sight feed bottle has been replaced by a flow-meter bottle (Fig 21) A chloroform bottle has been added This is regarded by some anæsthetists as of doubtful value

## ADMINISTRATION OF GAS-OXYGEN FOR THE PURPOSE OF MAJOR SURGERY

The patient is prepared with the same scrupulous care as if ether or chloroform is to be administered Half an

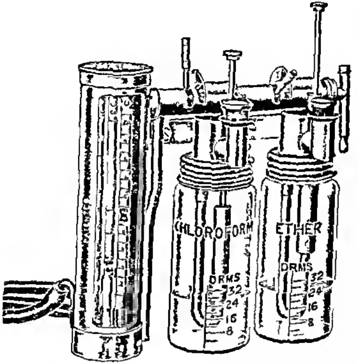



FIG 21 —Flow meter for nitrous oxide oxygen and carbon dioxide combined with a bottle for chloroform and one for ether (Coxeter)

hour before operation morphia gr $\frac{1}{6}$ and atropine gr $\frac{1}{100}$ are given hypodermically or the patient is treated with one of the basal narcotics The anæsthetist before beginning administration must look over the apparatus most carefully and satisfy himself that every part of it is

in perfect order, and that a sufficient supply of both gases is at hand

The inhalation is begun by the use of nitrous oxide alone, given "on the valves," and at no great pressure After a few breaths, oxygen is added very guardedly, the proportion being steadily raised during the first two minutes, after that point a further increase will not be necessary until several more minutes have elapsed The pressure at which the mixture is being given, as judged by the tension of the bag, is also steadily increased and should reach the maximum permissible within a few minutes Not only positive pressure, but also some degree of *re-breathing* is necessary Both can be produced by moving the lever of the Barth three-way tap into a position *between the points* marked "Valves" and "No valves" This manœuvre will cause part of the expiration to pass out of the apparatus while part returns into the bag With a little care in adjusting the lever and regulating the flow of the mixed gases we can secure some positive pressure in the bag, and just that degree of re breathing which gives the best results in the individual case

Theoretically it should not be necessary to touch the handles controlling the flow of gases from the cylinder heads at all, once the right rate of flow and the correct relation between the two gases has been established Actually, this state of perfection is not always attainable, and minor adjustments must be made from time to time

It is wise, particularly in one's early days, to give a trace of ether vapour during the latter part of the induction stage, and to maintain it until the operation is well under way Once the anæsthetist is satisfied that the narcosis is proving deep enough for the purposes of the operation, the ether may be shut off and will probably not be required again

Remember that *depth* of anæsthesia can be secured in three ways (1) cutting down the oxygen percentage, (2) increasing the tension of the mixed gases, (3) adding a little ether Of these, No 1 is most undesirable, and if carried to the least excess over a period of more than a minute or two may lead to an accident No 3 is the means for the beginner to rely upon until he learns the judicious and skilful use of No 2 The anæsthetist who is learning this method of anæsthetising must resolve that nothing shall tempt him to overstep the stage of dull pink colour, and moderate pupils If with gas oxygen alone he cannot get a satisfactory anæsthesia without resorting to oxygen starvation, let him not be ashamed to turn on his ether

Abdominal relaxation sufficiently complete to permit the surgeon to explore the abdominal cavity with ease is not readily secured by gas oxygen in a patient of robust type Fortunately, it is the weakly or the severely shocked who really *need* this form of anæsthesia, and in them abdominal relaxation is fairly easily obtained

Professor Crile as has already been explained, does not rely upon the inhalational anæsthetic alone He infiltrates each layer of the parietes with novocaine, thus producing a local anæsthesia If this method be faithfully carried out by the surgeon, a most complete relaxation of the muscles can be secured

Some American authorities now advocate the preliminary use of magnesium sulphate injected subcutaneously before gas-oxygen, and state that by this technique abdominal relaxation can be attained with ease

### McKESSON'S APPARATUS (Model G)

The principal features of this are —

(*a*) Mixing of the gases takes place in a mixing valve, and may be regulated in known percentages

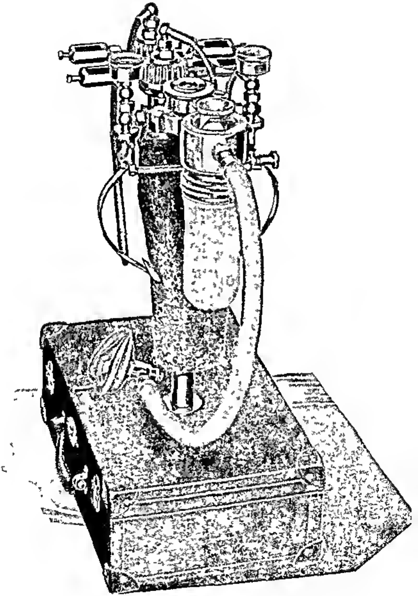


FIG 22.—McKesson's apparatus (Model G), lateral view.

(*b*) The flow of gases from cylinders to bags, of which there are two, one for each gas, is intermittent, under the control of two levers By this means the flow from cylinder to bag takes place only during inspiration, and a considerable saving of gases is effected Positive pressure may be obtained by adjusting the levers

(*c*) Re-breathing can be measured in whatever proportion is desired

(*d*) Pure oxygen may be supplied instantaneously under pressure

Those various features all possess advantages making for accurate control of, and rapid alteration in, the mixtures, economising the amount of gases consumed giving an accurate adjustment of re breathing, and allowing for the prompt use of pure oxygen in emergency An ether container is fitted and so arranged as to allow of varying amounts of ether being added to the gas and oxygen The apparatus may be used for gas and air instead of gas and oxygen if desired Although made in America it can be obtained with attachments for cylinders with the English standard thread.

### ADMINISTRATION WITH McKESSON S APPARATUS

Preparation for the administration consists in turning on at the stop-cocks one cylinder of each of the gases This permits the bags to fill By means of the automatic valves the flow of gases is immediately stopped when the bags are full and gases only allowed to enter during the patient s inspirations With the bags full, the regulator is set at pure nitrous oxide, and the facepiece applied accurately and comfortably Consciousness is rapidly lost and at the end of one or one and a half minutes the respirations become stertorous, and cyanosis develops

It is then necessary gradually to add oxygen by 2 per cent at a time until 6 or 8 per cent is reached If at

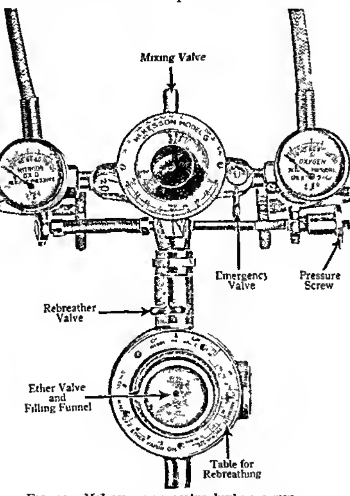



FIG 23 —McKesson's apparatus bird's eye view

any time the anoxæmia becomes too pronounced it may be necessary to allow one inhalation of 50 per cent or even 100 per cent oxygen, care being taken to limit the amount

to that required to correct the anoxæmia If it be over done the patient will come out After a variable time usually within six minutes the mixture suitable to the patient will be found and the regulator set at this per centage varying from 8 to 15 per cent Thereafter only slight adjustments will be called for as evidenced by the patient s colour respirations and response to stimuli

When anæsthesia is fully developed the re breather, which is graduated to permit of any percentage of re breathing is turned on and set at the desired level Ether may be added by turning on the ether regulator to the point required

## SECONDARY SATURATION

McKesson himself has described another method of inducing with nitrous oxide oxygen which he calls secondary saturation It must be used with caution and only after the administrator has acquired skill with the apparatus With those provisos it is of considerable value in securing a better degree of muscular relaxation McKesson describes the technique in the following words

In saturating a patient with nitrous oxide for the pur pose of securing the maximum degree of relaxation one necessarily approaches a certain degree of anoxæmia which may necessitate the use of the emergency valve forcing oxygen into the lungs if anoxæmia of too great a degree is produced

Anoxæmia is indicated when the pupils are fixed and begin to dilate when the respiration becomes slow forced and often associated with a general muscular tonic con traction In some instances however the muscular phenomenon is that of clonic spasm instead When these signs develop one breath of 50 to 100 per cent oxygen is administered *at once* and the mixing valve reset for a

mixture of gas and oxygen which, by the experience of the anæsthetist, it is deemed will be necessary When the breath of oxygen, just referred to, takes effect about ten seconds later, the musculature of the abdominal wall and other muscles will relax, and if the mixture is properly set and carefully watched, relaxation will continue Air inhalation quickly destroys relaxation

" Relaxation comes, not during the period of anoxæmia as a rule, but it comes after the oxygen has been administered and absorbed It is apparent that if too much oxygen is administered at this time, the patient will so far recover that light anæsthesia and muscular rigidity will again occur "

## ARTIFICIAL RESPIRATION WITH THE McKESSON APPARATUS

In the event of serious respiratory failure, with stoppage of breathing, the apparatus is well adapted for performing artificial respiration For this purpose the facepiece is held tightly to the face and the expiratory valve closed The emergency oxygen valve is opened and the lever at the oxygen side is pressed against the bag In this way oxygen is forced into the lungs under considerable pressure After a few seconds of this the facepiece is removed from the face for a few seconds to release pressure, corresponding to the act of expiration Those two actions are continued rhythmically till breathing is re established This rarely takes long, as the method provides very efficient artificial respiration with pure oxygen

A variant of the McKesson Model " G " apparatus, known as the McKesson " Nargraf," has now been on the market for some time Various modifications in the details of the machine have been made and attachments for chart-

ing blood pressure and respiration have been added The essential features however remain the same and the above description of the method of administration requires no substantial alteration

## THE BLOOD GASES IN NITROUS OXIDE AND OXYGEN ANÆSTHESIA

No one should embark upon the administration of this form of anæsthesia particularly for prolonged cases until he has thoroughly mastered the contents of Chapters III and IV In itself nitrous oxide is a marvellously innocuous drug but its administration may imply profound changes in the proportion of oxygen and $CO_2$ carried in the blood At the risk of repeating themselves the authors would again emphasise the following points —

(*a*) A certain amount of re breathing is not only economical but is also physiologically sound in that it *prevents the patient suffering from* $CO_2$ *deficiency*

(*b*) The type of breathing is our best guide as to the limits to be set to re breathing A depth and urgency of respiration which in the conscious subject would obviously indicate real respiratory distress will equally plainly indicate in the anæsthetised subject that undesirable excess of $CO_2$ is present in the blood and alveoli and that less re breathing must therefore be practised Sweating of the face is probably also an indication of the same thing

In making the above statements we are not losing sight of Cushny s work to which reference was made on page 25 In our personal experience the centre does *under nitrous oxide and oxygen anæsthesia respond quite* definitely to prolonged re breathing and one can only suppose that this form of anæsthesia is not sufficiently

deep to prevent some response to $CO_2$ excess, though it is very probable that such response is less than would be seen in the unanæsthetised subject

(c) Quick shallow respirations indicate anoxæmia, and the necessity for *increasing the supply of oxygen* The colour of the face and blood will usually give simultaneous warning, but in view of Bohr s discovery (page 45) we must remember that if there has been a prolonged period of deep breathing with the *valves in operation*, there may be $CO_2$ deficiency, and that under such conditions anoxæmia of the tissues, particularly of the nerve centres, may develop, even though the blood contain a fair proportion of oxygen, and be reasonably good in colour The type of respiration indicating anoxæmia must therefore, after valvular breathing, be taken as final evidence of that condition being present even though the colour of the face may suggest the contrary Nerve centres and heart muscles cannot long survive in anoxæmia, and the patient must have the benefit even of the slightest doubt

## GAS-OXYGEN FOR THE YOUNG

Most anæsthetists feel that gas oxygen is not suitable for children under eight or ten years of age In the child the tidal air wave is small and feeble, and is too weak to operate the usual expiratory valve There is therefore a fear that the valve will not open and that excessive re breathing may result Moreover, children cyanose very readily, and exhibit the signs of anoxæmia with alarming suddenness On the other hand, much of the surgery of the young arises out of such conditions as acute bone sepsis and gangrenous appendices, where the advantages of gas oxygen over any other anæsthetic are very obvious, and we therefore welcome with much

pleasure a very recent communication by Dr J Ross Mackenzie, of Aberdeen, in the *British Journal of Anæsthesia*, wherein he explains the methods whereby he has overcome the difficulties His two chief points are —

(*a*) To use a mask without valves, and possessing only a side vent through which excessive pressure in the gas bag, and also the expirations of the little patient, may escape by their own pressure

(*b*) To use a much higher percentage of oxygen than is usual for the adult Dr Mackenzie states that he finds 30 to 40 per cent of oxygen is required

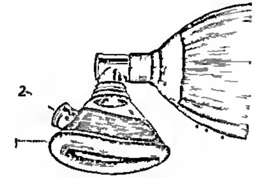



Fig 24 —Dr Mackenzie s mask

Dr Mackenzie s mask is shown in Fig 24 The side vent is placed as near the mouth as possible In it there are four apertures, one or more of which can be closed by rotating the screw cap cover He begins with all the four holes open, and closes one of them about every thirty seconds, until one only remains open The presence of these holes prevents undue pressure in the gas bag and allows a certain amount of the child s expiratory volume to pass out of the apparatus instead of going back into the bag

We have only to add that, while there is no doubt that Dr Mackenzie s own results are extremely good, and that his work has done a great deal to encourage others to use the method, we would not suggest its use to those inexperienced in gas oxygen for adults, among

whom the beginner should attain some real facility before anæsthetising children with it

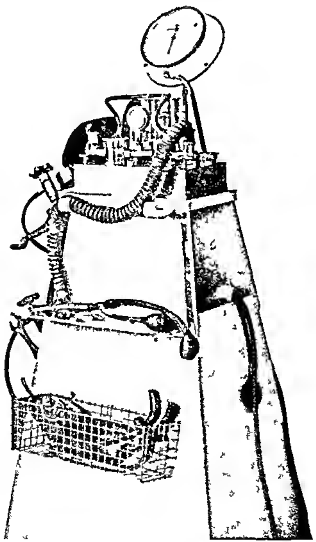


FIG 25 —Primrose s closed gas oxygen ether apparatus

## CLOSED CIRCUIT GAS-OXYGEN-ETHER ANÆSTHESIA

For several years experiments have been carried out with the object of extracting waste $CO_2$ from expired gas and oxygen The underlying idea is that with the removal of $CO_2$ the same nitrous oxide could be re breathed in definitely Jackson and Waters in the United States were the first to attempt to put the idea into practice and recently it has been taken up in this country by Evans Harris and Primrose The gas-oxygen apparatus is so arranged as to permit full re breathing while a container filled with soda lime crystals or caustic soda is interposed in the circuit and the gas oxygen passed through it By this means the $CO_2$ is extracted in passing through the container and provided no leakage occurs from the apparatus or at its connection with the patient the original charge of nitrous oxide ought to last throughout the administration A constant supply of oxygen must be kept running to replace the oxygen used up in meta bolism This appears to render it difficult to maintain a pure gas oxygen anæsthesia and to necessitate the addition of ether Another difficulty is the prevention of leakage To overcome this Primrose has devised a special mouth tube reaching to the pharynx At the pharyngeal end it is surrounded by an inflatable cuff When this is inflated by means of a hand pump a gas tight joint is secured In this way the ordinary facepiece is done away with the patient breathing through the pharyngeal tube

The method is still more or less in an experimental stage It opens up possibilities not the least of which is the reduction in bulk and weight of apparatus which would ensue from the resulting economy in the consump tion of nitrous oxide

# CHAPTER X

## ETHYLENE AND OXYGEN

There has been a considerable amount of experimental work done in the quest for an anæsthetic superior to those already known This has been directed largely to gaseous agents and among the gases tried are hydrogen, helium, ethylene, acetylene, and propylene * While nothing very revolutionary has resulted, a certain measure of success has been obtained with those of the hydro carbon series—ethylene, acetylene, and propylene Of the three, ethylene seems meantime to lay claim to superiority, and is the only one obtainable in Great Britain in a state of sufficient purity to be employed as an anæsthetic The discovery of its anæsthetic properties is due to the experimental work in the physiological laboratory of Luckhardt, of Chicago, ably seconded, on the clinical side, by Dr Isabella C Herb

### PHYSICAL PROPERTIES

Ethylene, $C_2H_4$, is a colourless gas with a peculiar, and decidedly objectionable odour, which has been variously compared to that of acetylene, onions, and of a box of matches, although in a state of purity it is said to be

* Very recently a new anæsthetic gas has been the subject of experiment viz cyclopropane The gas is costly and obtainable only in the U S A While glowing reports of the results obtained have appeared others have been more critical and it is not yet possible to determine its exact value

odourless The smell of the commercial preparation may be to some extent mitigated by flavouring with various oils, *e g* oil of eucalyptus or oil of lavender It has a specific gravity of 0 98, a melting point of $-169°$ C, and a boiling point of $-105°$ C It is very compressible, and for the purposes of anæsthesia is supplied by the British Oxygen Company in cylinders of 75 and 100 gallons capacity Those cylinders are fitted with a left hand thread at the outlet to distinguish them from those used for non inflammable gases Ethylene is highly inflammable and, mixed with certain proportions of air or oxygen is readily exploded Great care must therefore, be exercised to avoid using it near a naked light cautery, or diathermy apparatus

## APPARATUS AND ADMINISTRATION

As ethylene is administered in mixtures with oxygen and its manipulation as an anæsthetic has many points of similarity to nitrous oxide and oxygen the outfits employed for the latter serve very well also for ethylene Either Boyle s or McKesson s apparatus, described already, are *quite suitable* The percentage of *oxygen required*, however is somewhat higher than is the case with nitrous oxide varying from 12 up to 20 per cent, or even 25 per cent in young children

The anæsthesia may be commenced with nitrous oxide in order to save the patient the unpleasant odour of ethylene the latter being substituted when consciousness is abolished It is surprising however, how little resentment is evinced if the administration be commenced right away with ethylene The anæsthetic action seems to be developed so rapidly that the patient is hardly aware of anything objectionable At first 5 per cent oxygen

should be added, and after about one minute, when cyanosis begins to appear, this is gradually increased to the requisite percentage to maintain a slightly pink colour of the face It is then necessary to vary the mixture to the varying phases of the operation, just as with other anæsthetics Usually it will be found to be fairly stable at about 12 to 15 per cent Sufficient oxygen must always be allowed to prevent any decided cyanosis, as there is a marked depressant action on respiration, and later on the circulation, in presence of oxygen deficiency Partial re breathing should be employed

### ACTION

Ethylene and oxygen rapidly produces unconsciousness, usually without any marked excitement stage The type of anæsthesia closely resembles that which nitrous oxide and oxygen produces, except that (*a*) there should not be the same degree of cyanosis, owing to the higher oxygen content, (*b*) the respiration is of a quieter type, and (*c*) there is more relaxation of the muscles, rendering possible operative measures for which nitrous oxide and oxygen alone is barely adequate Thus it may be used for laparotomies, especially those below the umbilicus, with a greater measure of success

The eye reflexes correspond closely to those seen during nitrous oxide anæsthesia

The action of the heart is somewhat slower than the patient's normal, while increased in force The resulting tendency to higher blood pressure is usually counteracted by dilatation of the small blood vessels, which tends to produce somewhat increased hæmorrhage Circulatory failure is rare and occurs secondary to failure of respiration

Respiration is accelerated, but of a quiet type Respiratory depression is not easily produced if the oxygen percentage be kept sufficiently high Too strict a limitation of oxygen, however, is quickly followed by failure of the respiratory centre, much more quickly than with nitrous oxide Muscular relaxation may be best described as of a type between that produced, on the one hand, by nitrous oxide and oxygen, and on the other, by ether or chloroform

## DANGER

The anæsthesia takes a high place for safety Danger originates in respiratory failure, and should be treated immediately cyanosis becomes at all marked by increasing the percentage of oxygen if need be giving it pure for five or six inspirations If this point be observed it will rarely be necessary to have recourse to other measures, but in the event of a definite collapse the treatment described on page 195 (Treatment of Syncope) must be carried out

At the end of an administration recovery is rapid, consciousness returning in from one to five minutes, depending on the duration of the administration

The gas is non irritating to the respiratory mucous membrane and its use is rarely followed by respiratory complications

Nausea and vomiting are rather more frequent than after nitrous oxide but very much less frequent or severe than after ether or chloroform

## PRELIMINARY TREATMENT AND ADDITION OF ETHER

It is advisable except in the case of minor operations, to give a preliminary narcotic beforehand, the routine

being the same as preliminary to nitrous oxide and oxygen

During anæsthesia ether vapour may be added as desired In abdominal operations, particularly those in the upper abdomen, it is almost always necessary to add some ether if profound muscular relaxation is demanded It will be found that relaxation will be obtained with smaller quantities of ether vapour than are required with nitrous oxide It must be remembered that, with the addition of ether, the anæsthesia becomes composite and takes on some, at any rate, of the complexion of an ether anæsthesia

It would be safe to say that ethylene and oxygen will find a place where a somewhat profounder type of anæsthesia is desired than that obtainable by nitrous oxide and oxygen alone, but where a deep ether or chloroform anæsthesia is unnecessary or undesirable

## CHAPTER XI

## ETHER

THE drug commonly known as ether and otherwise described as ethylic ether or sulphuric ether has a chemical formula $(C_2H_5)_2O$ It is a transparent colourless fluid with a specific gravity of 720 to 723 A brand much used in the States has an S G of 713 only a point which is greatly emphasised by its supporters who claim that it volatilises quicker and therefore is more powerful in action The authors have in actual practice not found much difference between this brand and any good British one Quite recently another of the ethers—di vinyl ether—has been found to have anæsthetic properties and is said to be less irritating than di-ethyl ether

Ether is highly inflammable and volatilises readily at ordinary room temperatures Its boiling point is 96° to 98° Fahr Whether evaporating from a fabric such as gauze or from bulk in a jar ether cools very rapidly and the fall in temperature soon reduces the ease of its volatilisation This point is of some practical importance in anæsthetics and some years ago one of us made a number of observations hitherto unpublished with a view to ascertaining some definite facts in this connection His results will be found in Appendix I

*Ether vapour* is heavy—two and a half times heavier than air It therefore tends in a room to flow towards the floor and to remain for some time unmixed with the

general atmosphere. Since it is highly explosive, this constitutes a definite danger if any naked light or open fire is present. Everyone who handles ether should bear in mind these physical peculiarities of its vapour, and especially in cases where diathermy or the cautery are to be used. In such cases, if the region to be operated on is anywhere near the patient's face, ether must be ruled out. Several accidents, of varying degrees of severity, have occurred through overlooking this danger.

Ether is affected by prolonged exposure to bright sunlight, and also by prolonged bubbling through it of air, nitrous oxide, or oxygen.

The period of time necessary for changes of any importance to occur under any of the above conditions does not appear as yet to have been the subject of any accurate observations, but if there is in any specimen of ether a material change in appearance or odour, it should either be sent to the hospital laboratory for examination or presented to the theatre sister for use as a cleaning agent. Such contributions are always gratefully received.

Most of the ordinary impurities of ether are acid in reaction, while ether itself is absolutely neutral. Any specimen which turns litmus paper red should be sent to the laboratory for examination.

## SOURCES OF SUPPLY

Ethylic ether may be prepared either from ethyl alcohol or from methylated spirits. In the former case it carries, however, the cost of the duty imposed upon potable spirit, and since perfectly good anæsthetic ether can be prepared from the latter source, it is waste of money to use the more expensive article.

## IMPURITIES IN ETHER

The theory advanced some eight years ago that ether in a state of purity was not capable of producing anæsthesia has been convincingly disproved by the work of Dale King and von Leeuwen and care should be taken that ether used for anæsthesia should be as free from impurities as possible The best ether, however, is liable to deteriorate especially if exposed for a considerable time to light and air It should therefore be stored, prior to use in a sealed, stoppered bottle in the dark

There are a number of impurities which may be present (*a*) in an imperfectly prepared ether, or (*b*) in one not stored in accordance with the above precautions The commonest are ethyl sulphide, ether peroxide and acetaldehyde Those have been shown by Wesley Bourne to be toxic if present to the extent of ½ per cent

A recent suggestion by an American pharmacist is that ether should be stored in copper containers, and some of his work goes to show that by this means we may avoid the production of peroxides and acetaldehyde

## PHYSIOLOGY

Ether acts upon the nervous system like other anæsthetics as compared with chloroform however, the stage of excitation of each centre before its paralysis is apt to be marked There is therefore in some subjects, a greater tendency to struggle, but healthy subjects properly handled do not show much evidence of irritation of the cerebrum All however show some evidence of stimulation of the respiratory centre which is not prolonged *Prolonged deep and rapid respiration under ether is due to other causes than the action of the drug itself* It is of course

seen in closed ether but the active agent is excess of $CO_2$, not ether

The working margin of safety in ether, *i e* the stage between loss of spinal reflexes and the poisoning of respiratory centre, is much wider than in chloroform

Some experiments of Waller made many years ago showed that upon nerve tissue ether acts much less powerfully than chloroform, in the proportion, he found, of one to seven or eight These laboratory results have received entire confirmation by later workers who have estimated the actual vapour strength required of either drug to produce or maintain anæsthesia Roughly, to induce anæsthesia, we require 2 to 3 per cent chloroform, or 16 to 18 per cent of ether (*see* Appendix II)

## The Circulation

The first effect of ether is a temporary stimulation of the heart which beats more rapidly and more strongly, thus raising the blood pressure This effect is not very prolonged, like all other drug stimulation, it is followed by depression In the healthy subject properly anæsthetised, such depression is very moderate in degree and in a normal administration it is probable that the heart, after the first few minutes, is acting very much at its normal speed and force Ether is, however, a marked vaso dilator, and the net result upon blood pressure is a slight fall after the first few minutes

If the method in use is "closed," the pressure remains slightly raised for some considerable time, usually throughout the administration The slight anoxæmia induces a vaso-constriction, and the $CO_2$ excess, in the view of Henderson (*see* page 14), maintains a good return of venous blood to the heart and a satisfactory cardiac out

put For a note of certain blood changes resulting from ether and other anæsthetics, *see* Appendix III

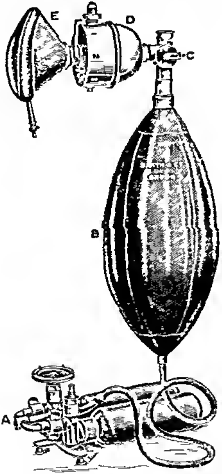



FIG [illegible] —Clover's ether inhaler with nitrous oxide attachment

## RESPIRATORY SYSTEM

In addition to the effect upon the medullary centre already referred to ether affects the respiratory tract

more profoundly than other anæsthetics The mucous membranes are irritated, and in some cases there is a great outpouring of mucus Though usually limited to the upper part of the tract (nose, pharynx, and trachea), the irritation sometimes extends deeply into the chest, affecting even the small bronchioles These unpleasant effects of ether are in the great majority of cases quite transient, after the first ten minutes no addition to the secretions is noticed In a minority however, the effect persists, the whole chest is filled with moist sounds, and persistence with the drug is impossible

*The kidneys* are always slightly irritated by ether, and if they are or recently have been subject to inflammatory disease, a very acute exacerbation is apt to follow the use of the drug In the healthy kidney this is not to be feared, nor does it seem to be an appreciable danger where one kidney is sound even if the other is the seat of gross organic disease necessitating its drainage or removal

## ETHER CONVULSIONS

Since Wilson drew attention in 1926 to convulsions arising during ether anæsthesia, many cases have been reported The convulsive movements commence in the muscles of the eye and face, spreading later to the limbs and becoming generalised They seem to be more frequent in presence of anoxæmia The complication is a grave one, and many of the cases have ended fatally Various lines of treatment have been suggested, such as the administration of oxygen with or without $CO_2$ a change from ether to chloroform, although this would appear to be a risky procedure, raising of the patient's head (reported by Daly to have been successful in cutting short a convulsive attack), the administration of certain

drugs such as adrenalin and coramine The methods which suggest themselves as most likely to be helpful are (a) the immediate withdrawal of ether (b) the administration of oxygen and the raising of the patient s head to relieve the anoxæmia and tendency to cerebral congestion and (c) the administration of coramine

No satisfactory explanation has been given as to the causation of these convulsions although many possible reasons have been adduced e g impurities in the ether impurities in accompanying oxygen idiosyncrasy to atropine among others All that may definitely be said is that one or more of the following factors have been noticed in the cases reported (a) deep anæsthesia (b) overheated ether or a very high theatre temperature (c) a relatively large dose of atropine (d) the patient a child or young adult and (e) the presence of a septic condition

## METHODS OF ADMINISTRATION

Many methods have been tried but those which at present hold the field are —

(1) Closed ether

(2) Open-ether more properly called the Perhalation Method

(3) The Vapour Method

(4) The Rectal Method (Gwathmey s oil ether)

(5) The Intratracheal Method described separately in Chapter XII

### (1) Closed Ether

The two inhalers originally brought out for this were Clover s in London and Ormsby s in Dublin At a later date Hewitt s wide-bore modification of the Clover was introduced

*The Clover instrument* (*see* Fig 26)* consists of a face-piece, a dome shaped ether chamber, and a one-gallon bag, usually attached to the top of the ether chamber by a T-shaped tube The details of the method by which the amount of ether inhaled by the patient is graduated are best appreciated by unscrewing the milled head at the top of the dome and withdrawing the tube which runs through it (*see* Fig 27) In the tube will be found two slots, one about half an inch above the other, and each extending for half the circumference of the tube Between these two slots the tube is divided by a diaphragm In any case, therefore, air passing up or down the tube must pass in and out of these slots

Now turn to the tubular space left in the dome piece, and examine visually and with the finger its interior On the one side of its middle will be found two slots leading into the circular ether chamber which occupies a large part of the dome On the other side will be found a small cavity, as deep from above downwards as the two slots combined, but *not* communicating with the ether chamber It is obvious that with the tube inside, if this cavity is opposite the slots in the tube, air will pass up the tube out of one slot and back into the other, without coming into contact with the ether at all If, on the other hand, the slots in the tube are opposite the slots in the ether chamber, the air passes over the surface of the contained ether, and volatilises some of it

Intermediate positions of the tube give a condition where part only of the air passes over the ether The indicator attached to the tube, combined with the figuring "0," "1," "2," "3,' 'full," to be found on the outside of the base of the dome, shows at any moment what proportion of the air is passing into the ether chamber

* In the figure the Clover is shown with gas valves and two-gallon bag *arranged for " gas and ether*

To use the instrument, fill the metal measure provided with ether, withdraw the stopper from the ether chamber, and pour in the ounce and a half of ether which the measure contains. Replace the stopper, and blow through

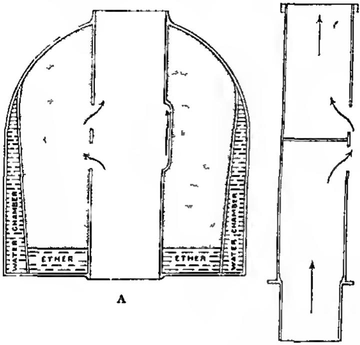



FIG. 27.—Diagram of a vertical section through the middle of Clover's inhaler. A shows the ether dome, B Central tube removed from apparatus.

the tube to expel any ether vapour which may have appeared in it. Leave the rubber bag at first unattached; the patient will feel more comfortable if during the first minute the top of the tube is open. With the indicator at 0, adapt the facepiece to the face and allow the patient

to breathe up and down the tube By rotating the dome, ether is then gradually turned on until the figure 2 is reached in the first minute The indicator is then slipped back nearly to zero for a second and the rubber bag slipped on during an *expiration* it must be moderately

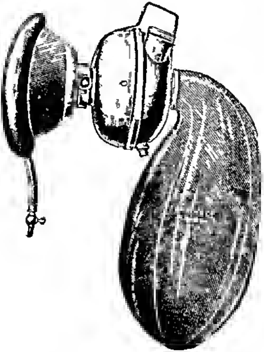


FIG 28 —Hewitt s wide bore ether inhaler

inflated to supply the requisite volume of air for respiration

The rotation of the dome is again begun and the indicator is made to travel away from the zero, until at the end of about five minutes it reaches full * After

* In many cases anæsthesia can be induced without pushing the dome past the figure 3

the first few minutes it will be necessary to give an occasional breath of fresh air, otherwise an undesirable degree of cyanosis will result, but it must be done with great discretion, or struggling will ensue. At the end of about five minutes anæsthesia should be fully established. A little extra ether is then poured into the chamber, the indicator pushed back to about "2" and the administration continued. One breath of fresh air is given in every three or four. Spells may be given with the bag off altogether, but during such periods the indicator will require to be advanced a little, and refills of ether provided more frequently than would be necessary if the bag were on.

*Hewitt's Wide-bore*

The principle of this is identical with that of the Clover, but the channels being wider, there is less mechanical interference with the ingress and egress of air. The actual construction differs also, in that to turn on the ether, instead of rotating the dome, one moves the indicator (*see* Fig. 28). The instrument certainly gives results a little better than those obtainable by the Clover, but it is heavier, and rather more bulky.

*Ormsby's Inhaler (see Fig. 29)*

This consists of a facepiece, a cage made of wire or thin steel slips and containing a sponge, and lastly, a one gallon bag which fits over the cage. In the facepiece is an air vent which can be either entirely closed, partially or entirely opened.

To use the instrument take out the sponge and warm it either by wringing it out of hot water, or better by leaving it a few minutes on the top of a hot steriliser. Push it back into the cage, open the air vent fully and, holding

the inhaler upside down, pour on to the sponge a measure full (about half an ounce) of ether Tell the patient to inhale deeply, and then catch the resulting expiration in the bag by quickly adapting the facepiece to the face at the appropriate second

After a few seconds, begin to close the air vent, when it will be found that the bag begins to wax and wane with each expiration and inspiration respectively After the first three minutes the inhaler must be removed, more ether poured in, the air vent opened again partially, and the inhaler again applied to the face After full anæsthesia is induced, the air vent may constantly be left partially open

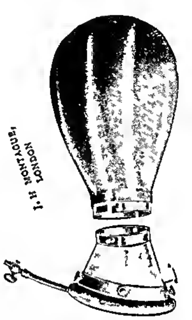


FIG [illegible] —Ormsby's inhaler The cage for the sponge does not show in the figure it projects upwards from the bag mount and is therefore enclosed in the bag

*N B*—It must be observed that the air vent is not valved, it is merely an opening through which part of the respired air may pass in and out without going near the ether sponge

In actual practice the induction stage of closed ether is almost invariably assisted by using either nitrous oxide or a small dose of ethyl chloride as a preliminary these methods are described in Chapter XVII

The question now arises, what *scope* is to be assigned in modern anæsthesia to closed ether methods Formerly *a large proportion of anæsthesias, long or short, were*

conducted by the closed method and while the greater number of anæsthetists no longer utilise them to the same extent as formerly, they may still be regarded as of the utmost value in a limited class of cases They are speedy in action, powerful enough to overcome the most refractory patient and with reasonable skill very safe On the other hand, the anæsthesia obtained is not of the most desirable type There is a great deal of salivation and mucous secretion from the respiratory mucous membranes the respiratory movements are deeper than in open methods from the excess of $CO_2$ present in the blood and this leads to a good deal of heaving of the abdominal wall which may be most troublesome to the surgeon if he is opening or closing that cavity * Moreover, after their use more headache malaise and vomiting occur then after open ether and perhaps a little more tendency to bronchitis or pneumonia For these reasons many anæsthetists and surgeons now object to their use in abdominal surgery though some still adhere to them for the induction stage passing to the open method when the patient is once well under

## (2) Open Ether

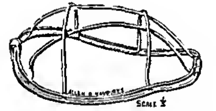
As already explained the strictly accurate term for this is Perhalational Ether but so cumbersome a terminology stands small chance of general acceptance

### *Apparatus*

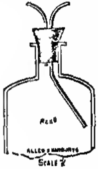
The essential points in a proper outfit have already been explained (*see* page 43) and are all well met by the

* All these drawbacks are capable of mitigation in the hands of those who use closed-ether habitually certain anæsthetists still prefer it to the open method and appear to achieve most excellent results frequently employing a little additional oxygen

mask and ether dropper introduced by Mr Bellamy Gardner (*see* Fig 30) The mask is covered with from twelve to sixteen layers of gauze, and lies on the gauze ring, shown in Fig 32A, which completes the fit between face and facepiece The dropper fits into the ordinary six ounce dispensing bottle, the long arm dips into the ether, the short one allows air to enter the bottle to replace the ether used A dropper can also be improvised by using a cork with slots cut at each side and with a gauze or wool wick inserted along one of these We find these



A



B

Fig 30—Bellamy Gardner s (A) open ether mask (B) ether dropper

uncertain in their action, however, with Gardner's dropper, a steady flow of *drops* of ether, slow or fast as required, can always be obtained once the student has acquired the knack of using the appliance

Ether is vaporised not only by the inspirations but also by the expirations of the patient, indeed, more ether will be vaporised by the latter than the former, since the air expired is necessarily warmer than that inspired The vapour so formed does not rise any great distance from the surface of the gauze, nor does it blend rapidly with the ordinary atmosphere of the room, its great weight compared with air causes it to flow in a

definite column to the floor of the theatre These statements can be easily checked either by using one s nose to locate the area where the smell of ether is strongest or by allowing a beam of light to come athwart the mask when the column of ether vapour descending to the floor can actually be seen By various devices a large part of this vapour of expiration can be retained in the area of the mask and so caused to be inhaled with the next inspiration thus effecting economy of ether used and reducing to a minimum the difficulties referred to in the succeeding section

To Mr Bellamy Gardner s outfit we add a folded towel pinned at one corner so as to form a short cone The base of this cone embraces the mask and face, through its upper aperture the anæsthetic is dropped on to the mask The cone can be rotated into the position most convenient for this purpose in any given position of the patient s head (Fig 32)

Dr Ogston of Aberdeen (*see* Fig 33) has had erected on his open ether frame several vertical struts united at their distal end by a ring Round these struts a towel is pinned thus converting the apparatus into a deep wide mouthed cone He lays great emphasis upon the width of the mouth as he has shown how necessary it is to be able to drop ether on to the whole surface of the gauze a thing impossible to do if the aperture of the cone at the top is narrowed

*Modified Ether Inhaler*

Dr F R Gusterson (Worthing) writes Having found Mr Denis Browne s ether inhaler very useful for anæsthesia in children I have modified it in the following details and use it as a routine for adults

(1) The face end has been made wider and the sponge

rubber facepiece dispensed with a piece of gamgee being used

(2) Two gas tubes have been inserted so that oxygen and $CO_2$ can be administered if necessary

(3) A lid with revolving shutter has been fitted This enables a certain amount of re breathing to take place easily controlled by rotating the shutter

I usually induce with ethyl chloride the shutter being off I go on as soon as possible to pure ether the shutter being

FIG 31 —Gusterson s Ether Inhaler

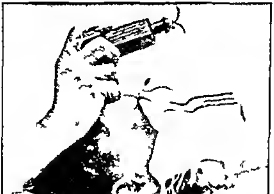
placed in position and gradually closed down By this method the patient only breathes a warm ether vapour a constant depth of anæsthesia can easily be maintained and the actual amount of ether used is very small For an abdominal operation lasting one hour including induction I use about 6 to 8 ounces of ether all told

I have to thank Messrs Allen and Hanburys for several helpful suggestions and for making this model

### *Problems of the Induction Period*

Open ether is not a powerful anæsthetic just not powerful enough for one to be sure that one can induce full

A —Open ether Ready to begin



B Open ether Condens ng towel in pos t on

FIG 3°

C.—Open ether. Correct method of holding mouth and jaw

D.—Open-ether. Alternative method of holding mask. The towel and gauze have been removed so as to show the tilting of the mask which this method is liable to cause

I FIG. 32A

anæsthesia with it alone, in a powerful subject The reason for this is shown in Appendix II, and may be here condensed by explaining that some 18 to 20 per cent of ether vapour is required to induce anæsthesia, while it is not easy to get more than 14 per cent off an open mask How is this situation to be met ?

Reference has already been made to one solution of the problem *A closed ether method may be used for in-*

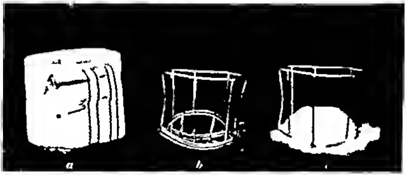




FIG 33 —Ogston's ether inhaler (a) Inhaler fully draped and ready for use (b) Frame of inhaler (c) Inhaler with gauze only but before towel is pinned round uprights.

*duction* and this practice is widely used We do not often adopt this course, fearing that the undesirable features of closed-ether may persist even after the change to an open method has been made

Another possibility even more widely favoured is to use *chloroform as the inducing agent*, and only to turn to ether when full anæsthesia is obtained To this plan we are strongly opposed It exposes the patient to the risks of the induction stage of chloroform which are much greater than those of the later stages Moreover, to develop the full advantages of open-ether, a preliminary hypodermic of morphia is often helpful and the drawbacks

of chloroform *plus* morphia are elsewhere mentioned (page 61)

The use of a *mixture of chloroform two parts, ether three parts*, presents the same disadvantage, but in a lesser degree In powerful or alcoholic patients we believe this to be the method of choice (*see* Chapter XVI)

Another plan, and one which only very slightly increases the risk to the patient, is to commence the administration with ethyl chloride This is spread over the surface of the mask drop by drop until a total dose of 3 or 4 c c has been used, in the case of the very muscular or alcoholic patient it may be necessary to use 5 c c The application of this initial ethyl chloride, the anæsthetic action of which is quickly developed, is immediately followed by the application of ether, also drop by drop, but at a decidedly more rapid rate than in the case of a straight ether administration from the outset With practice it is possible to avoid a gap between the actions of the two drugs and to guide the patient quietly through to a full ether anæsthesia The secret of success is to give the ethyl chloride slowly and steadily and immediately follow with a rapid application of ether

Lastly, there remains the plan of using *ether as the main inducing agent*, but assisting its action by the intermittent and most guarded addition of small quantities of $C_2E_3$ mixture In teaching it to students, too much emphasis cannot be laid upon the small quantities of chloroform mixture required or *permissible* *As a consequence of the perhalational method here advocated, every drop of chloroform which appears on the mask will, when volatilised, give a very much higher percentage of $CHCl_3$ vapour in the inspired air than the same quantity exhibited on the ordinary open chloroform mask* Once the student has

grasped this essential fact, ordinary care and intelligence will enable him to guard against a danger which is only existent if unappreciated

Ogston, by the use of his special mask, states that he finds no great difficulty in inducing by perhalation ether only, even in powerful subjects We, however, have had such steadily good results from the method described, that we feel inclined to adhere to it We are inclined to think that by using just the faint trace of chloroform above indicated and so avoiding the necessity for using quite so powerful an ether vapour as would otherwise be necessary, the result to the patient, both immediate and remote, may possibly be just a little better than if reliance is placed on ether only

### *The Administration*

For many of the hints given in this section we are indebted to the late Dr W J Ferguson, of New York, and Dr Hornabrook, of Melbourne

Success in inducing with open-ether is attained only by attention to a number of small details The student who thinks that some of them are too trifling for his notice is usually the man who informs you that induction by open-ether is impossible, the fact really being that he has not taken the trouble to learn, or has never had proper tuition The following are the points demanding attention —

(*a*) Always give a doze of atropine half to three-quarters of an hour beforehand, or morphia and atropine

(*b*) See that the patient is comfortable on the table Prop up his head and shoulders a little with pillows In powerful subjects, Hornabrook tilts the whole table down

(*c*) Adhere strictly to perhalation and to the drop method You will never induce with open-ether if the

whole volume of the respired air does not pass through the gauze

(*d*) Chat to the patient as long as consciousness can possibly persist Tell him he is doing very well Don t shout complicated instructions at him as to how to breathe it annoys and muddles him

(*e*) When the gauze ring and the mask are in position, allow one or two drops of ether to fall on the mask, then pause, in a few seconds the mild ether vapour so formed will soothe the upper respiratory tract and prepare it for the stronger vapours yet to come This does not waste time—it saves it

(*f*) When the administration is again begun, attend closely to the rate of dropping At first not more than one drop in three or four seconds is wanted The full rate of dropping cannot be attained for at least ninety seconds Let the drops fall on the whole surface of the gauze, not only on one part of it This prevents freezing

(*g*) Give no mixture for the first ninety seconds there after some five to ten drops every half minute or every twenty seconds according to type of patient Have the mixture bottle handy so that no time is wasted in changing bottles Stop the addition of mixture as soon as full anæsthesia is attained

(*h*) Slip the folded towel over the mask and tuck its base well round the chin and face Do this only after the first two minutes have elapsed

(*i*) As soon as the neck muscles are relaxed, turn the patient s head over to one side and let the hands assume the position described in Chapter III and illustrated in Fig 32

(*j*) The student is warned to discourage the too early attentions of the nurse or house surgeon These officials are naturally anxious to " get the patient ready for the

Chief and are apt to start cleaning up before the patient has lost all consciousness A man who is doing his level best to go to sleep derives neither pleasure nor profit from a wholly unexpected dab of ice cold methylated spirit upon his umbilicus

By the addition of a little $CO_2$ to the inspired air as described in an earlier chapter the depth of respiration can be considerably increased and the induction of ether anæsthesia made more rapid and pleasant

By the use of the method here advocated induction is singularly easy and successful in good subjects The struggling stage is either not represented at all or appears only in the form of the lifting of a limb and a slight occasional pause or catch in respiration Full anæsthesia is often announced audibly by the commencement of a gentle blowing *Once it is heard the anæsthetist may rest assured that a workable level of anæsthesia is either present or not far off*

*Amounts of Ether required*

If the above instructions are followed the amount of ether required is not excessive Anæsthesia is attained after the use of about 1½ to 2 ounces of ether and one or two drams of mixture The next forty to fifty minutes demand about another four or five ounces of ether no mixture at all Some practice is required before these small figures are attained The more practice the less ether is required

(3) VAPOUR ANÆSTHESIA

In a sense all forms of ether anæsthesia are vapour methods but in all forms so far described the patient has to vaporise the drug himself in a true vapour anæsthesia this is done for him and the *mixture of air*

and ether vapour propelled towards him One of the keenest advocates of this method is Dr Gwathmey, of New York He lays great stress also upon the necessity of warming the vapour, claiming that this measure will prevent the loss of heat to the patient incidental to the warming up in the air passages of the cold vapour usually supplied by other methods Pembrey and Shipway have carried the matter further and shown that by warming the vapour inhaled, we maintain body heat to a quite definite degree It is not only a matter of mechanically transferring so many calories from the apparatus to the patient The metabolism of the patient himself is stimulated, this alone could account for the fact that among patients who inhaled ordinary unwarmed ether vapour the rectal temperatures rose in 16 6 per cent, fell in 76 per cent, and was unchanged in 8 6 per cent, while with warmed vapour it rose in no less than 35 8 per cent fell only in 44 5 per cent and was unchanged in 19 8 per cent

### *Apparatus for the Vapour Method*

In 1913, Karl Connell described such an apparatus, which was then in use at the Roosevelt Hospital, New York The ether was vaporised by dropping it into a warm chamber Air was pumped into the chamber, and carried the ether vapour in known percentage, and at known pressure as shown by gauges Such mechanism is ideal, but would certainly be rather costly Its great value was that it informed us with certainty what proportions of ether in the atmosphere were necessary to induce and maintain anæsthesia (*see* Appendix II)

A simple mechanism was brought out shortly afterwards by Sir Francis Shipway, of Guy's, and is known as Shipway's warmed ether apparatus

It consists essentially of the following parts (*see* Fig 34) —

(*a*) A small hand bellows (B)

(*b*) An ether bottle with tube for delivery of air stream deeply into the fluid the exit tube of course does not

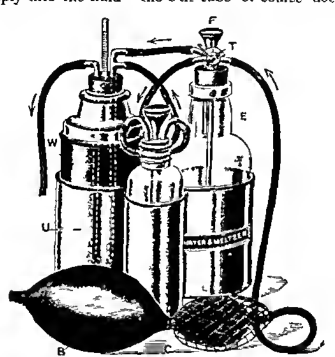



FIG 34 —Shipway's warmed ether vapour apparatus

dip in The bottle stands in a metal pan in which water at about 75° Fahr is to be placed (C)

(*c*) A thermos flask (W) in which is a metal tube (U) The etherised air passes along this tube and picks up heat from its walls The thermos is filled with water at about 120° Fahr

(*d*) A mask upon which a towel or gauze is to be

stretched, the rubber tube bringing the air and ether is brought through the covering material and delivers the anæsthetic vapour in the region of the mouth

(*e*) To the above there may be added a small chloroform bottle (C) In specimens of the instrument containing this convenience there has, of course, to be a regulating tap (T) at the head of the ether bottle, which will divert more or less of the air stream towards the chloroform

In using the machine, it is necessary to remember that from the physical point of view one is providing from the machine a small part only of the total volume of air required by the patient

The bellows is quite small, one squeeze of the hand will not supply more than about the equivalent in volume of one or two fluid ounces The larger part of the volume required by the patient has to be obtained from the general atmosphere, so that the percentage of ether which may be as high as 25 in the exit tube, will be greatly lowered by the time it reaches the patient s respiratory tract

Instead of the hand bellows, an oxygen cylinder may be connected to the machine and oxygen employed instead of air for vaporising the anæsthetics, and the apparatus may now be obtained with a bypass arrangement by means of which the oxygen may be led to the patient without being passed through the ether and chloroform bottles

The actual strength of ether breathed by the patient will depend upon —

(*a*) The force and frequency with which the pump is compressed (*N B*—It is, of course useless to pump during expiration)

(*b*) The depth of ether in the bottle

(*c*) The temperature of the water bath in which the ether bottle stands The warm water should only be put

in at the last moment before starting otherwise very strong ether vapour will collect on the surface of the ether and the first puff of the bulb will expel a highly irritant vapour towards the patient

With specimens of this machine which have the addition of the chloroform bottle it is perfectly possible to conduct even the induction stage of anæsthesia a mere trace of choloform vapour will be sufficient It is unnecessary to give detailed instructions for the use of the machine A preliminary consideration of the above physical facts together with a little cautious practice will enable the student rapidly to acquire facility with the method

## (4) Rectal Etherisation

For laryngoscopic and bronchoscopic examinations and for such operations as the removal of jaw or tongue there are obvious advantages in being able to introduce ether vapour to the blood per rectum since the mouth and air passages are thereby left free for the attention of the surgeon

Many years ago this was attempted by vaporising ether and propelling the vapour through a tube high up into the rectum This method was abandoned as it led to a good deal of inflammatory trouble afterwards Recently Dr Gwathmey suggested a new method of utilising the rectal route which has largely overcome this objection

### *Gwathmey s Oil Ether Method*

This consists in passing into the rectum a mixture of olive oil and ether The bowel is first carefully washed out and an hour before operation the patient receives a hypodermic of morphia gr $\frac{1}{6}$ atropine gr $\frac{1}{150}$ A

suppository of chloretone gr v is also passed into the rectum to act as a local sedative Half an hour later the patient is put into the left lateral position, a soft catheter attached to a funnel is passed some six inches up the rectum, and the mixture of oil and ether poured into the funnel It is wise to take at least five minutes to introduce the whole dose

The following table shows the dosage required —

| Age of Patient | Strength of Ether in Mixture | Quantity of Mixture required |
|---|---|---|
| *Under 6 years* | 50% | One ounce to each 20 pounds body weight (no preliminary morphia) |
| 6 to 12 years | 55% to 65% | Do Do |
| 12 to 15 years | Do | Once ounce to each 20 pounds body weight (but use $\frac{1}{12}$ gr morphia) |
| 16 years and upwards | 75% | One ounce to each 20 pounds body weight with $\frac{1}{4}$ gr morphia as a preliminary * |

In practice, then, for the ordinary adult, one uses eight ounces of the mixture, six ounces of which are pure ether The oil and ether require to be shaken together, but remain blended long enough for introduction

In five or ten minutes the patient begins to feel a rather pleasing numbness and tingling in the lower, and later the upper extremities, and drops quietly to sleep in about twenty minutes In a large proportion of cases it is necessary to deepen the anæsthesia by the use of the

* On the question of a maximum strength of the mixture *see* remarks on page 141 Some authorities do not now favour more than 50 per cent *of ether in the mixture*

open mask for a few minutes, but once a deep anæsthesia has been thus obtained the absorption from the rectum will balance the loss in expiration and maintain a good anæsthesia for three quarters of an hour at least

On return to bed of the patient, the nurse passes two tubes, placed side by side, as high into the rectum as she can, the end of a Higginson syringe is inserted into one of them, and a considerable quantity of soap and water is pumped gently into the bowl, escaping down the second tube The washing must be continued until all smell of ether is removed Finally, the soapy water itself is washed away by a little saline

We have given the original Gwathmey method a fair trial, and believe that it is reasonably safe and has some scope More especially, it is of real value in the following

(*a*) Panic struck patients who cannot face the ordeal of induction by ordinary methods

(*b*) Nose throat, tongue or face operations where intratracheal ether is not available, or for some special reasons not suitable It must, however, be remembered that the drug will be present in the exhalations, and that a light or cautery cannot be used near the mouth

In estimating the possibilities of the method, however, it is essential to avoid misconceptions In well-chosen and well managed cases the apparent ease of induction and maintenance of anæsthesia is very striking, and may lead the casual observer to believe that here at last is the anæsthetic millennium—a method so easy, simple, and safe that to use vulgar language, any fool can give it to any patient The dangers of such a view have been well brought out by Prof Hatcher in a recent series of articles, and after perusal of his work we feel it necessary to make the following points quite clear —

(*a*) The essential features of ether anæsthesia are

not materially altered by the fact that the drug is absorbed into the blood through the intestinal wall instead of through the lung alveoli It will still be exhaled from the respiratory organs, and can therefore produce irritation and subsequent inflammation in that system almost, though not quite, as readily as if it also entered by that path Overdosage could be quite as easily produced—indeed more so—as by the ordinary methods, and in case of danger arising, the obvious remedy would be painfully slow in operation

(*b*) It is impossible to predict with certainty what dose will be required to secure the necessary degree of anæsthesia in any individual case It is wise, therefore, to aim at under dosage, leaving a margin which can be filled with an inhalational method This additional administration may in nose and throat cases be intermitted for long periods without danger of the patient feeling any pain or becoming unmanageable, while in other groups of cases, *e g* abdominal, we secure by this mixed method all the advantages of easy induction offered by Gwathmey s technique, while retaining the flexibility upon which modern anæsthetists have learnt to pride themselves and modern surgeons to rely

(*c*) Although we personally have not seen serious cases of colitis following oil ether, we recognise the possibility of such occurring and we therefore agree with Prof Hatcher in his advocacy of the use of a 50 per cent rather than a 75 per cent strength of ether in the mixture as a maximum The actual amounts of ether advocated by Gwathmey are in our experience not excessive, so that if the percentage strength of ether is reduced, the total quantity of the mixture may be correspondingly increased (*see* page 139, and footnote)

## CHAPTER XII

# ENDOTRACHEAL (OR INTRATRACHEAL) ANÆSTHESIA

THE administration of anæsthetics by endotracheal insufflation resulted from the researches of Meltzer and Auer in the U S A It was subsequently taken up there by Elsberg and later in this country by Shipway, Boyle and Kelly Of recent years Magill and Rowbotham have added much to our knowledge of the method, and the former has evolved many improvements in technique and apparatus

Meltzer and Auer proved that by passing a tube well into the trachea, to within half an inch of its lower end and driving a current of air through this tube, which is of such a size as to allow a return current to pass between its outer wall and the inner wall of the trachea, the pulmonary alveoli could be ventilated and the normal interchange of gases carried on independently of any respiratory movement The pressure requisite for the attainment of this passive state of the respiratory muscles is dependent on two factors (*a*) the size of the endotracheal tube relatively to the diameter of the larynx, and (*b*) the force of the insufflated air By mixing with the insufflated air a percentage of ether vapour this artificial ventilation of the alveoli could be accompanied by anæsthesia, so that the method provides us both with the means of administering an anæsthetic and with an excellent means for performing artificial respiration Elsberg recorded a

case of a patient who had taken morphia with suicidal intent, on whom artificial respiration by this method was kept up for twelve hours, without any respiratory movements taking place, recovery ultimately ensuing

In ordinary endotracheal anæsthesia it is not necessary, in fact it is not advantageous to employ pressure sufficiently high to abolish the movements of respiration altogether. In many operations, however, the control of

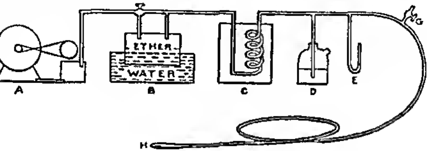



FIG 35—Diagram of intratracheal apparatus

respiration which is possible, *e g* in thoracic and upper abdominal surgery, is of value

When first evolved the method was employed only for ether anæsthesia and the apparatus consisted of (*see* Fig 35)

(*a*) A pump for producing air current (A) or a cylinder of oxygen

(*b*) Ether chamber and various regulating taps (B)

(*c*) Device for warming vapour (C)

(*d*) Safety valve (D)

(*e*) Manometer (E)

(*f*) Bypass (G)

(*g*) Connecting tubing and catheter (H) for passing into the trachea

Although many variations have been brought out, and

other anæsthetics than ether used, the essential ... of the above description and diagram remain incorporated in almost all apparatuses For instance, a warming chamber is valuable so that cold air or gas will not be blown into the lungs A safety valve is essential It is constructed in such a way that the pressure may be set

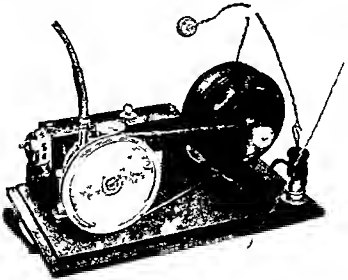


FIG 36—Electric blower to supply current of air for intratracheal anæsthesia

at a certain level, usually about 20 mm mercury, and operates to prevent this level being exceeded so safeguarding against any damage being done to the lungs by a sudden burst of gas or air through the apparatus A manometer is a convenience as affording constant visible indication of the pressure The value of a bypass is somewhat questionable It was first incorporated so that the air or gas current could be deflected away from the tracheal tube passing directly into the atmosphere By

this means pressure in the lungs was released, giving them the opportunity of collapsing, and allowing the normal movements of respiration to come into play With the lower pressures which are now employed, however, the need for this has very largely been abolished Fig. 36 illustrates an electric blower for generating the air current when air is to be the vehicle employed

Ether may be added to the insufflation current in

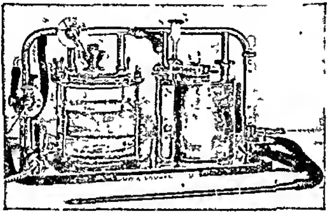


FIG 37.—Kelly's intratracheal apparatus

different ways In Kelly's apparatus this was achieved by directing the air current over the surface of ether in a large jar. The percentage of ether vapour taken up by the air depended: (*a*) on the level of the ether surface, *i.e.* its proximity to the top of the jar to which were connected the affluent and effluent pipes, (*b*) on the area of ether surface exposed, and (*c*) on the rate of flow of the air current.

Another type of apparatus permits the air to bubble through the ether instead of merely blowing over its surface. In this case precautions have to be taken, by

obtruding some kind of gauze diaphragm, to prevent drops of ether being blown into the lungs

And lastly, as in Shipway's apparatus, ether may be dripped into a vaporising chamber through which the air current passes, this chamber being so arranged as to allow only vapour to be carried over

Whatever the method adopted it is necessary that a maximum delivery of 15 to 18 per cent ether vapour be obtainable, that means be provided for cutting this down to whatever vapour strength is demanded, and that it be possible to cut off the supply of ether entirely so that air alone may be driven to the patient

In the foregoing description the assumption has been that air is being used as the insufflating vehicle, this to avoid rather clumsy verbiage As a matter of fact in the modern type of apparatus provision is made for delivering air, oxygen, or nitrous oxide and oxygen, as, for example, in Magill s (Fig 38)

Provision is also made in this apparatus for partial re-breathing by the introduction in the circuit of a rubber bag, and for the addition of chloroform if desired

## TECHNIQUE OF ENDOTRACHEAL ANÆSTHESIA

Owing to the fact that most of the obstructive complications of ordinary anæsthesia are overcome in the endotracheal method the actual maintenance of the anæsthesia presents few difficulties, *i e* from the time that the tracheal catheter is in position It is in the preliminary stage, the introduction of the catheter, that difficulties arise These, however, can largely be overcome by the increasing skill which practice gives

In order to abolish the reflex actions which would occur in a normal wakeful patient anæsthesia must first

be induced The patient may have a preliminary hypodermic of morphia gr $\frac{1}{6}$ and atropine gr $\frac{1}{100}$ or scopolamine gr $\frac{1}{150}$ One or other of the last two is to be

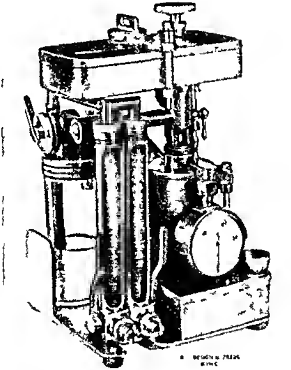


FIG 38—Dr Magill's nitrous oxide—oxygen—ether—chloroform—carbon dioxide—apparatus

recommended to provide dry mucous membranes A 5 per cent cocaine spray applied to the pharynx and epiglottis is helpful, and permits of intubation with a lighter degree of general anæsthesia In its absence a deep

anæsthesia is induced and the introduction of the catheter proceeded with

## INTUBATION

A choice of two routes is available oral and nasal If the Oral Route be the choice the intubation is best carried out through a special type of laryngoscope, in preference to tactile methods as there is less risk of damage being done Many types of laryngoscope are available A convenient form is Magill s Endotracheal Spatula It is easily withdrawn without disturbing the catheter and provides for the battery being carried in the handle After attention to the preliminary anæsthesia the patient s neck is slightly extended The tip of the spatula is then inserted between the incisor teeth, slipped backwards along the dorsum of the tongue, and brought to rest on the tip of the epiglottis A slight tilt forwards is then given to the handle of the instrument without allowing the spatula to slip off the epiglottis until a view of the cords is obtained The catheter which may be single or double, is then slipped along the spatula its tip pushed between the cords and onwards till it rests just above the bifurcation of the trachea Catheters are marked with a ring which should be at the level of the incisor teeth when the tip is at the correct level Dr Magill has suggested the use of a double catheter, one afferent and one efferent, as being productive of the best results through the assurance of an adequate

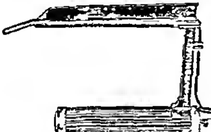


FIG 39 —Dr Magill s endotracheal spatula

expiratory current A graded series of gum elastic catheters from 8 to 18 English gauge, should be available, and the choice made of the size appropriate to the patient, usually about No 12

When the catheter is in position its distal end is connected to the apparatus by means of the tube provided and the anæsthetic current turned on The act of intubation is almost invariably accompanied by coughing, but

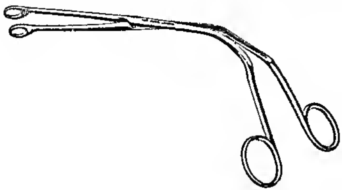


Fig 40 —Dr Magill s intratracheal tube holding forceps

with the catheter in position this can quickly be checked by the introduction of the anæsthetic

*The Nasal Route* —Magill has shown that with a deeply anæsthetised patient, if a rubber tube be passed along one nostril, the patient's neck being in normal position, neither flexed nor extended, and without lateral torsion, and gently pushed onwards, the curve which it naturally takes will in many cases direct it into the trachea Intubation may frequently be performed in this way If unsuccessful a gum elastic catheter may be introduced through one nostril, then, with the help of a laryngoscope, the tip picked up by special forceps (Fig 40) and pushed between the cords

Whichever route is employed difficulty will at first occur through the tendency to insert the catheter into the œsophagus instead of the trachea The stimulation of the cough reflex already referred to, is very helpful in giving assurance of correct intubation

## MAINTENANCE OF ANÆSTHESIA

With intubation successfully accomplished little remains to be said The anæsthetic chosen whether gas oxygen ether or a combination of the two is blown through the apparatus and graded to the requisite depth of anæsthesia Towards the conclusion of the operation the anæsthetic should be shut off and the lungs well ventilated with air or oxygen, or with a $CO_2$ oxygen mixture so that when the catheter is withdrawn the patient s reflexes have returned After certain operations, particularly plastic operations about the nose, mouth, or face it is very advisable to leave the catheter undisturbed for some hours or even days, as very serious asphyxial symptoms have been known to arise in these cases when the catheter has been withdrawn immediately the operation was completed

## INDICATIONS

The perfect ventilation which endotracheal anæsthesia ensures is strongly in its favour so much so that some anæsthetists make it almost a routine method The risk of damage to the cords and trachea from friction appears to be negligible and the incidence of lung complications is certainly no higher than with other methods It is particularly suited to —

(*a*) Operations which involve the patient being placed in awkward positions *e g* laminectomies

(*b*) Operations about the neck where obstruction to the air way is probable (not including exophthalmic goitre)

(*c*) Plastic operations on the head or face

(*d*) Perhaps prolonged upper abdominal operations

## CHAPTER XIII

## CHLOROFORM

### PHYSICAL CHARACTERISTICS

Chloroform is chemically trichlor methane, $CHCl_3$. It is a colourless, transparent fluid, with a specific gravity of 1 491 at 17° C Its vapour is even heavier than that of ether, approximately four times heavier than air It is not inflammable, but the action of an open fire or naked flame tends to break it up into hydrochloric acid and phosgene, both of which are highly irritant gases to all who breathe them The patient suffers, but since all the other occupants of the theatre are also affected, warning is given before serious harm has been inflicted

Chemically pure chloroform is a somewhat unstable product, but the addition invariably made to it by the producers, of a trace of alcohol, prevents any serious risk of decomposition in bulk It should be neutral in reaction and have an agreeable, non-irritating odour, departure from the normal in either respect indicates the possibility of the presence of acids or aldehydes, and the necessity for referring a specimen to the laboratory

Like ether chloroform may be obtained from pure ethyl alcohol or from methylated spirits, and the remarks made in the chapter upon ether apply to the case of chloroform also A third source of supply is acetone, from which perfectly good chloroform can be produced

## PHYSIOLOGY

Chloroform is an irritant to the skin and mucous membranes. A drop left on the skin and covered over with

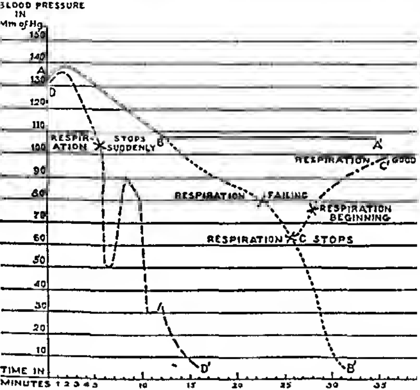



FIG 41 —Diagrammatic representation of various blood pressure curves obtainable with chloroform

Line ABA' represents curve desired in normal chloroform administration
Line ABCB' represents gradual overdosage
Line ABCC' represents recovery by inversion
Line DD' represents syncope from vagal inhibition, in its course, two attempts of the heart to "escape" are shown

impermeable material will produce a deep and painful blister. A drop falling into the eye, if not instantly

washed away, produces a very powerful inflammatory reaction, and many eyes have been seriously damaged from carelessness in this respect Such incidents might prove actionable, and heavy damages be given

The special peculiarities of the action of chloroform upon the nervous system have already been emphasised in the account given of the physiology of ether (*see* page 114) Its action upon the *circulatory and respiratory systems* has been the subject of many researches, and of much embittered controversy The literature is therefore very extensive, and the account of it must be severely condensed The following may be taken as a brief resume of present-day opinion (*see* Fig 41) —

(*a*) In every case of chloroform administration there is a fall of blood pressure

(*b*) If the drug be presented in weak concentration (2 per cent or less) the fall is gradual and even (line AB)

(*c*) If the same strength be persisted in unduly, the respiration will cease at a time when the blood pressure is still well above zero (line ABCB′)

(*d*) The fall of pressure is due to diminished force of cardiac action and at a later stage also to vasomotor paresis

(*e*) The cessation of respiration accompanying such a B P curve as ABCC′, is due partly to fall of blood pressure in the vessels supplying the medullary centre, partly to gradual poisoning of the centre itself by the drug That the fall of B P in the cerebral vessels is in itself one explanation of the cessation of respiration was proved many years ago by Leonard Hill in his inversion experiments Just at the stage when respiration had ceased, the anæsthetic was withdrawn, and the animal inverted into the head-down position The B P in the carotid at once began to rise and natural respiration was resumed (*line A′BCC*)

There remains for consideration the type of blood pressure curve which is represented on the diagram as DD′, in which a sudden and frequently fatal, fall occurs during the induction period. Much work was done in the first decade of this century to elucidate the causes which underlay such calamitous incidents, and until quite recently the work of Embley, and of Schaffer and Scharlieb was accepted as having finally proved the following further points —

(*f*) With *high concentration* of chloroform vapour the fall of blood pressure is rapid and is apt to become suddenly precipitous (line DD′)

(*g*) The cause of these sudden falls is inhibition of the heart by over activity of the vagus* cutting the vagi always terminates the effect unless delayed so long that the animal is dead in an animal fully under atropine, these vagal actions cannot be produced

(*h*) If the heart is inhibited by vagal action the respiration ceases at once usually after one deep inspiratory sigh

(*i*) An inhibited heart may escape from vagal action before the animal is dead, frequently however, the inhibition persists and the animal dies

(*j*) Struggling and breath holding in the early stages of induction cause sudden falls of blood pressure Many observers believe that these falls also are due to vagal activity, others hotly deny this All were united in believing that to *press* chloroform upon a patient who is struggling and holding the breath is fraught with grave risk of causing sudden syncope

(*k*) The abnormal irritability of the vagus above re

* The theory of vagal inhibition was accepted as finally proved by the Special Chloroform Committee of the British Medical Association in *their report dated July 1910*

ferred to is a feature mainly of the induction stage dis appearing once full anæsthesia is developed

(*l*) It is an undoubted clinical fact that there is a risk of sudden arrest of heart s action if the operation is begun before the stage of full anæsthesia is reached The accepted explanation of such accidents was furnished by postulating a reflex inhibition acting through the vagal centre already rendered hypersensitive by partial chloroformisation

## VIEWS OF GOODMAN LEVY

This worker has demonstrated in animals that the heart is sometimes thrown by chloroform into the condition of fibrillation—a delirium of the cardiac muscle from which recovery is rare It occurs in the early stage before full anæsthesia has been reached and is predisposed to by the infliction of trauma The practical outcome of this is that the induction stage of chloroform should not be unduly prolonged and that the operation should not be begun until the third stage is fully developed

We may summarise Dr Levy s views by saying that in his opinion danger from vagal inhibition is non-existent and that all the sudden failures of circulation appearing in the induction stage are due to cardiac fibrillation the essential cause of which is *intermittency* of administration or the commencement of the operation at a stage before anæsthesia is fully established and the tendency to fibrillation has passed It must be accepted that Levy has demonstrated the possibility of cardiac fibrillation and has indicated quite clearly its determining factor namely intermittency and insufficient depth of anæsthesia Therein he has certainly done yeoman service to the science of anæsthesia for the two factors upon which he places all the emphasis are only too prone to appear in the practice

of inexperienced and nervous administrators To the authors' mind, however, Levy has gone too far in his attitude that vagal inhibition from the use of vapour strengths of too high percentage is not to be regarded as a real possibility, or at any rate not a dangerous one As Levy is one of the strongest advocates of the use of inhalers which will supply to the patient an atmosphere containing a known percentage of chloroform, the difference in view is on most counts not vital, since most workers (certainly the authors) strongly agree that the use of very weak vapours during the induction stage is not necessary —probably not desirable, and that to give chloroform intermittently is to give it badly Where, however, the authors do join issue with Dr Levy is on the treatment of the incident referred to in para (e) From the very beginnings of the history of chloroform, struggling and breath holding have always been regarded with great anxiety, the exact causation of the sudden tragedies which sometimes followed these phenomena may or may not be vagal inhibition, indeed Professor Leonard Hill gave of them an explanation which did not need to take any account of the vagus nerve But in the whole history of the subject one fact stands out clearly, namely, that practical anæsthetists and laboratory workers alike were of opinion that if marked breath holding, with clenching of the jaw and development of a trace of cyanosis, should occur during any stage of chloroformisation, it was the anæsthetist's duty to intermit the administration, to clear the air way, and to allow one or two free inspirations of fresh air before continuing the administration Faced with such an incident, the authors would still feel it their duty to follow the old rule, but they freely admit that if the principle of administering a constant atmosphere of reasonable chloroform strength be followed,

serious breath holding is very uncommon, and therefore any indication for interruption of the administration rarely present

During his work on this subject, Levy further demonstrated that the introduction into the circulation of *adrenalin* during incomplete chloroform anæsthesia was very liable to induce fatal cardiac fibrillation He thus furnished the explanation of a number of deaths which had occurred in the practice of nose and throat specialists Since the publication of Levy's work, the rule has been absolute that if *adrenalin* is to be used in a case requiring chloroform anæsthesia the arenalin must *precede, not follow* the anæsthetic

Hill in a series of very interesting electrocardiographic investigations into the behaviour of the human heart in anæsthesia has observed disturbances in the induction period with chloroform as the anæsthetic which are corroborative of the clinical evidence of the dangers associated with this period

His finding is that Chloroform was found to produce gross disturbances of rhythm in eight of sixteen cases investigated ranging from simple 'vagal' arrhythmia to supra ventricular paroxysmal tachycardia but generally of the nature of multiple ventricular extra systoles The disturbances were generally transient, unassociated with clinical circulatory symptoms and occurred usually in healthy hearts With one exception they occurred during induction were not related to operative procedures other than direct vagal stimulation and were generally abolished by deepening anæsthesia' and "Struggling on the part of a patient during induction, and poor air way with consequent embarrassed breathing and anoxæmia during operation were much more potent causes of disturbance than operative manipulation'

(Ian G W Hill, *Edinburgh Medical Journal,* September 1932)

### ADMINISTRATION

Basing upon these views as to the action of chloroform, and upon the lessons of practical experience, we may formulate definite rules for giving the drug

### GENERAL PRINCIPLES FOR GIVING CHLOROFORM

(*a*) Give chloroform evenly, not spasmodically

(*b*) Increase the vapour strength of chloroform gradually from zero until 2, 2½ or 3 per cent at most is reached at the end of two or three minutes,* maintain that strength until full anæsthesia is obtained The degree to which the percentage may be lowered after full anæsthesia has been established, and the time at which such lowering may begin, vary a good deal with the individual patient It also depends upon the nature of the operation, which may or may not demand a deep anæsthesia throughout its course Many patients need a continuance of the same strength as was used to complete induction for the first ten or fifteen minutes, in some cases it may be necessary to continue it for as long as thirty minutes Long operations which do not demand deep anæsthesia may frequently be completed under very low percentages (1 per cent or even less), experience alone can guide administration to a final conclusion as to the correct treatment of each individual case, but in general one tries to use as small a percentage as is consistent with maintaining an anæsthesia deep enough to prevent respiratory reflexes (*see* page 54)

* Levy states that 3 5 or even 4 per cent is necessary for very robust cases and evidently does not hesitate to use it when he considers it necessary

(c) Be guided chiefly by the patient's respiration Chloroform kills by stopping the heart, but in the immense preponderance of cases, evidence of failure of respiration appears in ample time to give warning of approaching circulatory failure The eye reflexes give confirmatory evidence of the depth of anæsthesia, but the superlatively important thing is to *maintain a free air-way, and be sure the patient is using it*

(d) If serious struggling and breath holding occur, withdraw the anæsthetic until the patient "resumes normal

### METHODS OF ADMINISTRATION

The logical application of such general principles would be to use an instrument which gives a definite and known percentage of chloroform, variable at the wish of the administrator Many such machines have been brought forward, and while none of them have obtained general acceptance, a description of the best known instrument will be given, as the reader may as a house-surgeon meet with it, and with a surgeon who wishes it to be used

### VERNON HARCOURT'S INHALER

In principle this is a 'draw over" instrument, the patient's own inspirations are the motive power Passing over the surface of the fluid drug, the inspired air picks up from it a known percentage of vapour The other system available for the construction of percentage chloroform instruments is the "plenum", in this the vapour is propelled to the patient by a pump

In appearance, the inhaler resembles the letter T, with a rubber facepiece attached to the lower end of the vertical limb (*see* Fig 42) The T portion itself is made of metal

tubing of a definite size in cross section One end of the horizontal limb admits pure air, the other, air which has passed over chloroform and picked up from it a certain proportion of vapour The proportion of the total inspired volume of air which passes through each of the ends is regulated by a lever seen at the junction of horizontal and vertical limbs and the exact percentage of chloroform being inhaled is indicated by a series of numerals marked on the dial over which the lever moves These figures are correct provided that —

(a) The chloroform receptacle is not shaken (this would greatly increase the percentage)

(b) The temperature of the chloroform is not allowed to fall below 13° C To ensure that this cannot take place without the knowledge of the administrator two coloured beads are thrown into the chloroform At the desired temperature of the chloroform (16°–18° C) the blue bead sinks to the bottom the red one nearly to the bottom Below 16° C both beads float and when this is observed, the chloroform vial is warmed up in the palm of the hand At the point 16° C the blue bead sinks and the warming must stop when the red is also sinking, otherwise an undesirable addition to the vapour strength yielded will occur

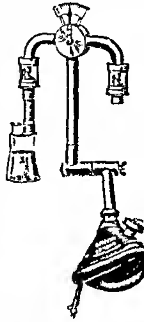


FIG 42 —Vernon Harcourt s percentage chloroform inhaler

(c) The respirations remain of average depth Abnor-

mally shallow breaths increase the percentage above that indicated on the dial, abnormally deep breathing has the contrary effect (Levy)

The inlet of the chloroform container may be constricted by a device supplied with the instrument, the use of which causes a more powerful stream of air to be drawn over the surface of the fluid with each inspiration,

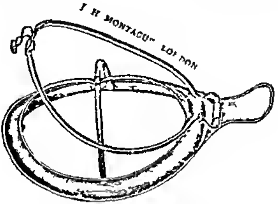



FIG 43—Schimmelbusch's mask

and thus to vaporise it more quickly The device consists of a tube which fits into the mouth of the chloroform bottle and is wider at one end than at the other With the wide end pointing downwards we get a maximum vapour strength of 2 5 per cent, with the reverse position a full 3 per cent can be obtained

The facepiece is made of rubber, and must be closely adapted to the face, in its side is seen the expiratory valve Inspiratory valves are present at each end of the horizontal limb

**OPEN METHOD**

The appliances requisite are —

*(a) A mask—Schimmelbusch's is the best known*

(Fig 43) as elsewhere explained, it does not accurately fit the face

(*b*) Material to stretch on the mask —The best is two layers of domette or one of flannelette surgical gauze is so light that heavy drops of chloroform are apt to ' spark " through it and burn the skin of the face lint rapidly

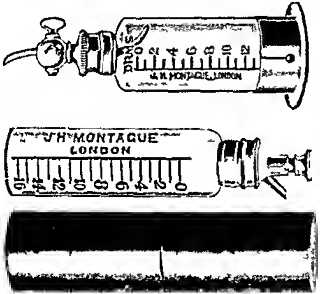



Fig 44 —Chloroform drop bottles

becomes sodden the drug drips away from its edge instead of vaporising properly

(*c*) A good drop bottle of which many varieties are marketed (Fig 44), it is essential that it should be capable of producing definite *drops* the old method of intermittent ' douching ' of chloroform is much less accurate

It is not possible by the open method to be mathe-

matically accurate with percentages, but the necessary appliances are simple, easily transported, and practically always at hand If the student learns to use it, and while doing so *to think in percentages*, he will achieve as good results as or better than he will with percentage instruments While he may not have in front of his eyes a dial which shows the percentage graphically, observation of the patient will inform him whether the percentage being given should be maintained, raised, or lowered The only remaining point for him to realise, then is how in practice such regulations of percentage strength can be achieved by the open method The strength of the vapour will depend upon three factors —

(*a*) Nature of the material used on the mask

(*b*) Size and shape of the mask and closeness with which it is adapted to the face

(*c*) Amount of chloroform exhibited on the mask

To ensure uniformity of result, two of these factors should be kept constant, and the necessary increase or decrease of vapour strength achieved by varying the third Always use the same type and thickness of material and the same type of mask, and allow the mask to lie lightly on the face If the amount of chloroform is then regulated by a strictly "drop" method, results of great uniformity may be obtained by the open method

It is of no value to use more of the drug than will just keep moist a certain surface area of the material, any quantity in excess of this will run by capillary action to the edge of the material, and so on to the face of the patient or at any rate into the sulcus at the edge of the mask, if any

For open administration, Levy teaches the use of a domette cover divided into halves, quarters eighths, and sixteenths When thoroughly moistened with chloroform

on a mask of the shape and size used by Levy, the resulting percentages achieved are approximately 3·2, 1·6, 0·8, and 0·4. A study of these figures will help the student to think in percentages when administering chloroform by the drop method (*see* Fig. 45). It is to be noted that Levy teaches an open method which is strictly perhalational; the mask fits the face accurately.

## THE JUNKER INHALER

This instrument was originally introduced as an attempt to achieve a percentage method. Air is pumped through a certain depth of chloroform contained *in* a bottle, and the vapour brought to the patient in the facepiece shown in Fig. 46. The calculations by which it was sought to establish this as a reliable dosimetric or percentage method are of no great value. From that standpoint the instrument has not achieved success. It delivers to the patient a *small quantity of high percentage vapour* which is diluted by a much larger quantity of air inspired by the patient from the general atmosphere, and the final percentage inhaled by the patient is therefore no more accurately known to the administrator than in the open method.

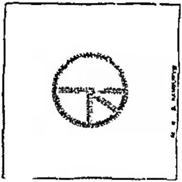


FIG. 45.—Covers designed by Levy for use with open chloroform mask.

The instrument is, however, of considerable value for tongue and jaw cases where anæsthesia *has* to be maintained for some considerable time after the mask with

which anæsthesia has been induced has had to be removed to give access to the surgeon

Fig 46 shows the instrument as usually marketed It consists of —

(a) A hand bellows

(b) Chloroform bottle A mark cut on this shows the

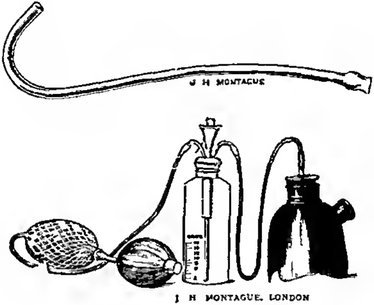



Fig 46—Junker s chloroform inhaler showing hand bellows bottle and mask Alternatively to the latter the nasal tube shown above may be used

level to which it is to be filled if more than the proper quantity be poured in droplets of fluid chloroform are apt to be blown along the exit tube, with dangerous results

For convenience and neatness it is usual to make the exit surround the inlet tube The entering air bubbles through the chloroform and a stream of air and

chloroform vapour passes out from the exit tube.* It is unnecessary to give a detailed account of the use of the instrument, but the student must remember the following points:—

(*a*) The amount of chloroform vaporised will depend on the vigour of the pumping, the depth of fluid, and the temperature of the chloroform. In order to achieve uniform results, it is therefore necessary to keep up a steady but not excessive pumping, to warm up the bottle occasionally by holding it to the palm of a disengaged hand, and to watch that the level of the chloroform does not fall too low.

(*b*) The pumping should be timed to synchronise with inspiration: a puff of vapour delivered during an expiration will be wasted.

## ADVANTAGES AND DISADVANTAGES OF CHLOROFORM

The light portable appliances which are alone necessary for chloroform anæsthesia, the comparative cheapness of the method, and the *apparent* ease with which its administration may be conducted, are all great temptations to its use. Those who feel the temptation strong upon them are advised to remember the following quotation from the writings of Professor Leonard Hill:—

"Chloroform is a drug used by the young anæsthetist with the utmost hardihood, and until he has had the misfortune in his practice to meet with a death caused by it, he derides the danger of the drug, and asserts that its safety merely depends on the care and skill of the administrator. After losing his patient, he falls to descanting on

* The student should be careful to be sure that the bulb is attached to the *inlet pipe*: if by accident it be slipped on to the outlet pipe the first compression of the bulb will eject a stream of liquid chloroform from the instrument. Omission of this precaution has been the cause of fatalities.

the unavoidable dangers of the drug, dangers which he is now the first to maintain cannot be met by any degree of skill in administration"

The most distressing, the least excusable, and probably the most common chloroform fatalities are seen in administrations given for the most trifling conditions, such as opening abscesses or extracting teeth

Apart from the immediate danger, there is a growing feeling among anæsthetists that the delayed toxic action of chloroform plays a bigger part than was generally recognised Short of the typical "delayed chloroform poisoning," which will be dealt with later, it seems to be fairly generally accepted that chloroform anæsthesia is often followed by an obscure upset of metabolism, and that this, after a serious operation, may be enough to turn the scale and cause the death of the patient

In general, we use chloroform if for any reason ether is not applicable For examples of cases of this description, the reader is referred to the chapter upon the choice of anæsthetics

## CHAPTER XIV

## ETHYL CHLORIDE

CHEMICALLY this drug has the formula $C_2H_5Cl$ It is a colourless fluid so volatile that it boils at ordinary room temperature Its vapour is highly explosive, and the fluid itself very inflammable The drug is supplied by the makers in small tubes with a metal end which can be opened by pressing a little lever (*see* Fig 47), varying in type with the tubes made by various makers Two brands are sold by each firm, one is chemically pure, intended for use as a general anæsthetic, the other is not so pure, and is only sold for local anæsthesia Such a product is not suitable for inhalation

### PHYSIOLOGY

The special points in the physiology of ethyl chloride may be briefly summarised as follows —

(*a*) After a trifling preliminary rise, the effect of the drug is to lower the blood pressure appreciably In the human adult subject, this fall becomes appreciable when more than 3 c c have been given, if the dose exceed 5 c c a fall of 30 to 40 mm of Hg is probable—occurring as it does within a period of perhaps twenty or thirty seconds such a fall cannot be regarded as without significance

(*b*) The cause of this fall is diminished cardiac output from weakening of heart muscle The vagus though not

paralysed, does not appear to be unduly irritable, as it does with chloroform


FIG 47
*Tube of Ethyl* Chloride

(c) The respiratory centre is at first perceptibly stimulated and respiration is therefore deeper and quicker than normal The stimulant effect *rapidly passes away* and gives place to a stage of depression

In the majority of cases, death appears to take place from paralysis of the respiratory centre, the heart still showing a little power of contraction after respiration has ceased *There is therefore a fair prospect* of recovery if artificial respiration be resorted to promptly

## METHODS OF ADMINISTRATION

### OPEN METHOD

The extreme volatility of the drug has discouraged most anæsthetists from giving it upon an open mask * Hornabrook, of Melbourne, advocates this system, however. His mask fits the face accurately, and his whole method is strictly perhalational He uses some 4 to 6 c c of the drug for a child, 6 to 8 c c for an adult, and achieves his anæsthesia in a minute to a minute and a half He also advocates open ethyl chloride as a preliminary to open ether

* Dr J A H Barton of London was certainly the first to describe an open method of administering ethyl chloride in a paper to the Society of Anæsthetists in 1906 but our own trial of the method was prompted by Hornabrook s paper

## Closed Method

This is the usual means employed A variety of inhalers has been produced on the market, one of which is shown in Fig 48 Essentially all consist of —

(*a*) A facepiece which must fit the face with reasonable accuracy

(*b*) A 1-gallon rubber bag attached to the mask by a T piece

(*c*) A glass vial, with numerals from 1 to 6 marked on the outside to facilitate the measurement of the drug in c c Into this the drug is squirted from the maker's tube The vial is attached to the T-piece (or alternatively the bottom of the bag) by a rubber tube

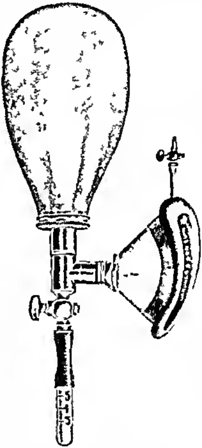


Fig 48 —Ethyl chloride inhaler

The form of inhaler illustrated in Fig 48 was originally designed by Dr J W Bamfield Daniell, then of Edinburgh, and now Lecturer in Anaesthesia at Cape Town, who with Drs Guy and Luke did much to popularise ethyl chloride in this country

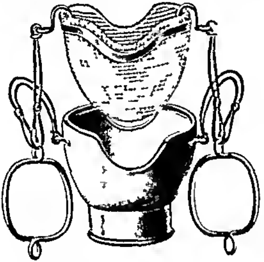
To use such an inhaler, the glass vial is first detached from the rubber tube, and the chosen dose of drug squirted

into it A child of five or six will require 3 c c, an adult up to 6 c c, this dose should never be exceeded, and except in the cases of robust males or alcoholics 5 c.c should be regarded as the maximum The vial is then rapidly reconnected with the inhaler The facepiece is adapted to the face, care being first taken to place between the teeth a mouth prop or a gag This enables one to get immediate access to the mouth when the inhaler is removed The patient is then told to breathe deeply once or twice During the inspiration the mask is lifted slightly and the ensuing expiration is then caught in the bag by pressing down the mask on to the face To volatilise the drug there are two alternative methods In the one part or the whole of the dose is tipped into the rubber bag by elevating the vial A far better is the Vapour method almost universally used in Edinburgh owing to the teaching of Dr J H Gibbs who designed it A tumbler is filled with hot water, and the bottom of the glass vial is allowed first to touch and after a few seconds to be immersed in it Some thirty to forty seconds suffice to vaporise the whole of the dose

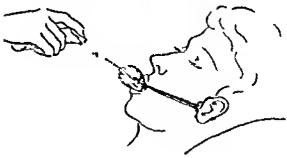
If given by a closed inhaler it is very necessary to avoid marked anoxæmia Enough fresh air must be admitted to prevent more than a slight degree of cyanosis If due attention be paid to this rule ethyl chloride may be administered in the sitting position

A method of administering ethyl chloride for operations within the mouth has been elaborated by Dr Borchardt of Berlin Dr Blair Gould (*British Medical Journal* 16th June 1934) describes the apparatus and technique He has found it useful in dental surgery and in tonsil and adenoid operations The apparatus consists of a mouthpiece containing a bag of very absorbent material permeable to air Into this fits a

nosepiece consisting of a wire frame over which the same material is stretched. Both are provided with elastic



A



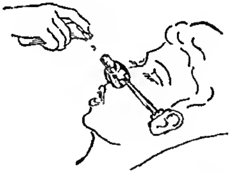
B

Fig. 49.—Borchardt's ethyl chloride inhaler.

attachments fitting round the ears and from these an extension passing behind the occiput making the apparatus self retaining. The administration is commenced as an oral one later by a lingeing arrangement first the

nosepiece is swivelled to fit over the nose when the drug is given both by mouth and nose Finally the mouthpiece is swivelled on to the top of the nosepiece, and the anæsthesia continued nasally Borchardt recommends the

C



D

FIG 49A —Borchardt s ethyl chloride inhaler

employment of ethyl chloride mixed with 15 per cent of added constituents, valerian camomile, peppermint, and alcohol By this means the boiling point is raised and freezing on the fabric prevented He claims that valerian reduces excitement and after sickness

## SIGNS OF ANÆSTHESIA

Ethyl chloride is very rapid in its action some sixty seconds availing to produce quite a deep anæsthesia *Respiration* is at first deepened and quickened as full anæsthesia is attained it remains rather deeper than normal, and is accompanied usually by light snoring The colour should remain perfectly good the pupils show marked dilatation, the corneal reflex is abolished, and good muscular relaxation is attained

With no anæsthetic is it so essential as with this, to become acquainted with the type of respiration normally to be expected, and to watch for any departure therefrom with cat-like vigilance The other danger signal is the pupil It should be dilated, but not excessively

Once anæsthesia is established, the inhaler should be removed, and the surgeon may begin his work He will have for its completion some eighty to ninety seconds against the forty to fifty available after nitrous oxide With ethyl chloride there is a somewhat prolonged "analgesic" stage The patient is partly conscious and may even be phonating, but seems unconscious of the infliction of pain unless very severe measures are being used

## THE SCOPE OF ETHYL CHLORIDE

When first introduced, it was expected by enthusiasts that the lightness and portability of the drug itself and of the necessary inhaler would enable ethyl chloride to oust nitrous oxide from its recognised place in surgery and dentistry These high expectations have for several reasons not been fulfilled In the first place, this drug is essentially a "single dose" anæsthetic Most authorities view coldly all attempts to prolong anæsthesia by repeated

or continued administration Secondly, ethyl chloride has a mortality rate very much greater than nitrous oxide if doses sufficient in themselves to produce anæsthesia are habitually used (*vide supra*) The introduction of Gibbs' "vapour" method has done much to mitigate the risks, but even then, this anæsthetic cannot approach the high level of safety rightly credited to $N_2O$ Moreover, it leads to after vomiting much more commonly than its rival

In many schools these considerations have been held so powerful that ethyl chloride has been entirely abandoned It is however, a very valuable drug for the following purposes —

(*a*) The removal of tonsils and adenoids For this operation, the speed with which the patient (usually a child) loses consciousness, the pleasant type of anæsthesia and absence of all serious asphyxial phenomena, and the rapid reappearance of the cough reflex when once the inhaler is removed, are all strong recommendations

(*b*) The extraction of teeth, especially in children

(*c*) As an adjuvant to gas, or gas-oxygen (*see* Chapter XV)

(*d*) As a help to the speedy and comfortable induction of "closed-ether" (*see* Chapter XVII)

## CHAPTER XV

## MIXTURES OF NITROUS OXIDE AND ETHYL CHLORIDE

Dr Guy, formerly Dean of the Edinburgh Dental School, introduced some years ago a method of giving ethyl chloride in mixture with nitrous oxide Guy's objective was to utilise the many excellent features of the drug without incurring the risks which are apparently inherent in it when a dose sufficient in itself to induce full narcosis is used Given in mixture with gas, a much smaller dose suffices

His original apparatus is shown in Fig 50, the details are shown in Fig 51 The horizontal limb of a three-way gas tap is prolonged half an inch In each side of the prolongation is a hole The bag mount has in its side also one hole, which is connected by a universal ball and socket joint, with the rubber tube to which the ethyl chloride vial is attached An indicator on the outside of the bag mount and a mark upon the outside of the horizontal limb of the three-way tap serve by their apposition or the reverse to show whether the ethyl chloride vial is in direct continuity with the interior of the inhaler For purposes of description, Dr Guy

Fig 50 —Guy's inhaler for $N_2O$ and ethyl chloride

calls these two positions, "in register" and "out of register"

To use the instrument, the ethyl chloride vial is removed, and the side pipe attached to a cylinder of nitrous oxide The indicator of the three-way tap is put at "air" and the bag mount "in register" The bag is then filled with gas by opening the head of the cylinder The

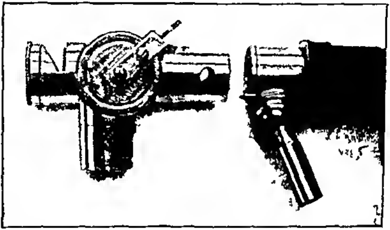


FIG 51—Guy's instrument for gas and ethyl chloride Details of valve piece and bag mount showing side tube for attachment of ethyl chloride vial

bag mount is now put "out of register," and the side tube disconnected with the cylinder The bag, being closed remains full of gas

A suitable dose of ethyl chloride is now squirted into the vial To an adult Dr Guy gives 3 c c on no account is this dose exceeded, children take $1\frac{1}{2}$ to 2 c c—even adults often get less than 3 c c The vial is now attached to the side tube again, and the inhaler is ready for use

*After application of the mask to the face, the three-way*

tap is at once pushed over to "no valves" and the patient re breathes the gas in and out of the bag for some six or eight respirations The bag mount is now turned round into "register," and the ethyl chloride tipped into the bag In a further twenty five seconds the mask may be removed and the operation begun

The available period of anæsthesia is eighty to ninety seconds, counting from the instant of the removal of the inhaler

This method was in use for some years at the Dental Hospital of Edinburgh, no instance of danger to life was ever seen With so small a dose of ethyl chloride the erect position necessary for the purposes of dentistry is perfectly safe

This inhaler, of course, will serve admirably for giving ethyl chloride without gas, and in Edinburgh is habitually used for giving the drug by the "vapour" method

In 1911, Dr Guy and one of ourselves modified the method so as to permit the use of oxygen with the nitrous oxide The inhaler which they then introduced serves also for nitrous oxide and oxygen, unaided by ethyl chloride, and the author has by its means given gas-oxygen to a considerable number of major surgical cases He now uses a sight-feed for long cases, but has found no reason to abandon or even modify the method and apparatus as first published by Dr Guy and himself, in so far as dental and short surgical work is concerned

In Fig 52 will be found a diagram showing the method by which the oxygen is introduced The 1-gallon oxygen bag is either attached directly to a cylinder or suspended on an upright as shown in Fig 53 In either case, the bag is, before the administration, moderately filled with oxygen, one bagful will suffice for a short anæsthesia, and the supply of the oxygen from the cylinder is there-

fore turned off at once For long cases, of course, a small trickle of oxygen into the bag is required to replace the gas used

In the outlet pipe from the oxygen bag is placed a ball syringe of 2 ounces capacity A valve in the pipe obliges the flow of oxygen to take place in one direction

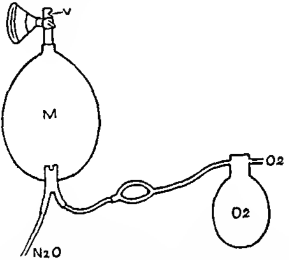


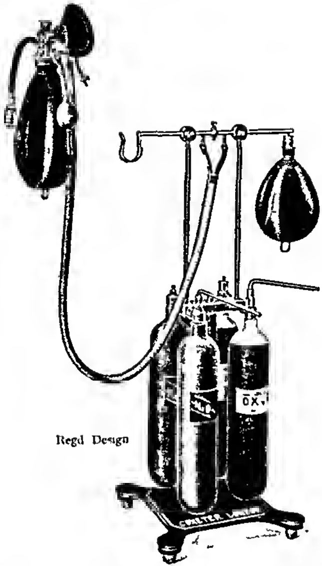

FIG 52 —*Diagram of the method introduced by Dr Guy and the author for giving nitrous oxide and oxygen with or without ethyl chloride*

only when the bulb is squeezed viz from oxygen bag to inhaler

The remainder of the apparatus is identical with Guy s original inhaler except that the bag is of 2 gallon capacity and is perforated at its base by a Y-tube, one limb of the fork bringing in the nitrous oxide the other the oxygen

### METHOD OF USE

A few breaths of pure nitrous oxide gas are usually allowed on the valves *Re breathing is then instituted*




DESCRIPTION OF THE APPARATUS

Two 100-gal cylinders of nitrous oxide
Metal upright and crutch riveted to gas-stand.
30-gal cylinders of oxygen.
1-gal oxygen bag
Arm supporting the oxygen bag
2-oz bulb or pump each compression of which sends forward a charge of oxygen from the oxygen bag D to the gas bag
Bag mount three-way tap and ethyl chloride attachment.

FIG 53—The Guy Ross nitrous-oxide and oxygen apparatus for use with or without ethyl chloride

and the addition of oxygen begun The amount required to each type of patient can only be learnt with experience but the average is one full compression of the bulb every ten seconds If anæsthesia is not complete at the end of one minute, put the indicator to "valves" again, and allow the patient nearly to empty the bag Then push back the indicator to "no valves," and refill the bag with nitrous oxide by opening the cylinder with the foot key Some four to six compressions of the bulb are made while the nitrous oxide is running in The time will now have come to add the dose of ethyl chloride if it be judged necessary at all This will have been placed in the vial before the administration is begun After emptying the ethyl chloride into the bag of the inhaler, anæsthesia should be complete in twenty five seconds

The same small doses of ethyl chloride are used as is the case with Guy s original method

After a little practice under supervision, students at the Dental Hospital learn to use this method safely and well No example of risk to life has arisen after many years daily experience

## CHAPTER XVI

### MIXTURES OF CHLOROFORM AND ETHER

The mere addition of ether does not remove all the undesirable features of chloroform anæsthesia A heart poisoned by excess of $CHCl_3$ does not respond to ether stimulation Nevertheless, C E mixtures of varying proportions have great value The less lethal drug takes on part of the work of the more dangerous one, it also keeps the respiratory centre active Viewing mixtures as dilute chloroform, it is also obvious that there will be with them a greater margin of error in dosage than with the pure drug

Some chemical change takes place when the two drugs are mixed for heat is evolved, of the nature of this change we are ignorant

The first mixture introduced was known as ACE, and consisted of one part absolute alcohol, two parts chloroform, and three parts ether Alcohol evaporates very slowly, and if it be introduced at all it should be in much smaller proportion Schafer's mixture is one part alcohol to nine parts chloroform Neither of these mixtures is now much used The most useful combination is two parts chloroform and three parts ether, and is known as $C_2E_3$ In special cases, one part of chloroform to two parts ether may be better

#### METHODS

*Cones* of varying type were at first extensively used for mixtures The best known is Rendle's It is made of

celluloid, and is perforated at the top by a series of small holes through which the anæsthetic is introduced. A sponge is packed into the upper part of the cone, and a flannelette cover completes the appliance. The objection to the use of this and kindred cones is that since chloroform evaporates more slowly than ether, the more dangerous drug is apt to collect in the sponge, completely altering the strength of the vapour after a time. This fault is remedied to a large extent by the open drop method now used.

## THE OPEN (DROP) METHOD

For this the mask and ether dropper of Bellamy Gardner are admirably suited (Fig. 30). As regards material, one layer of flannelette does very well, or the cheap cotton towels which used to be known in Edinburgh as "penny towels" in the pre-war period. The mask should fit the face with reasonable accuracy; there is no reason why a gauze ring should not be used to ensure this if the administrator is careful to adhere strictly to a "drop" method.

The bottle into which the dropper is inserted should be of different *colour* to those in which pure ether is habitually carried. This is a greater safeguard against a dangerous forgetfulness than a mere label.

As already said, the anæsthetic must be given by a strict "drop" method. "Douching" at frequent intervals gives results far inferior.

THE TYPE OF ANÆSTHESIA is a compromise between that of chloroform and open-ether. Respirations and colour are better than with pure chloroform, not so good as with open-ether. The size of the pupil is also intermediate.

SCOPE.—As elsewhere explained, there are many patients to whom open ether cannot well be given; the greatest

number of these can take a mixture perfectly, and C E. should certainly be chosen in preference to pure chloroform when possible For refractory cases, it serves admirably as the inducing agent before the use of open-ether.

## CHAPTER XVII

## SEQUENCES

By a sequence we mean a method in which anæsthesia is partially or wholly induced by one anæstbetic or one method, and maintained by another The methods mentioned in Chapter XV, as devised by Dr Guy for dental purposes are examples which have already been sufficiently described

### *C.E. MIXTURE—ETHER SEQUENCE*

Of the method of inducing anæsthesia by *C E*, and turning later to *open-ether*, we have also already spoken One thing remains to be said in this connection Learn to judge the appearance of the type of patient who will require this alternative to open ether induction, and use the sequence to such patients from the beginning Don't start off with open ether, and find out in a few minutes that the patient is too obstreperous A change from mixture to ether is harmless, the reverse process needs much care

The sequence of *C E to closed-ether* was advocated by Hewitt as a means of dealing with very alcoholic men, and for this purpose has great merits The mixture is given until the stage of struggling is just about to commence a point which experience enables one to fix with considerable accuracy The remainder of the induction is conducted by a closed ether inhaler, either the Hewitt wide bore or preferably the Ormsby The ether indicator

which stands at about "one" when the inhaler is first applied, may be advanced very rapidly, full ether strength being attained within a minute or two. As soon as rebreathing is begun with either of these instruments, it is very striking to watch the rapid and apparently safe subsidence into anæsthesia of the most troublesome patient. The struggling is cut short and greatly minimised in violence, and a stage which under $CHCl_3$ might have presented some considerable risk of secondary syncope is thus eliminated.

### NITROUS OXIDE AND ETHER SEQUENCES

This is a method greatly superior to the induction by closed-ether described on page 120. Instead of the 1-gallon bag of the Clover or Hewitt Instrument, the valve piece and 2-gallon bag of a gas apparatus are attached to the head of the ether inhaler (Fig. 28, on page 121).

Once the gas bag is inflated from the cylinder, the supply of gas may be cut off. A few breaths of gas "upon the valves" are given until the bag is half empty; the valve tap is then pushed over to "no valves" and rebreathing begun. Ether may be turned on a few seconds later, and the strength of the vapour may be increased more rapidly. Three-quarter strength of ether may be attained as a rule in ninety seconds. *There is very little* likelihood of struggling in this method.

### ETHYL CHLORIDE AND ETHER

This is a valuable method for short operations, being easily portable, speedy and safe in action, and fairly agreeable to the patient. Some anæsthetists use this induction method as a prelude to open-ether.

The Clover (or Hewitt wide-bore) instrument is interposed between *the facepiece* and *the* T *of the ethyl chloride* inhaler, as shown in Fig 54. A small dose of ethyl chloride only is requisite; for an adult, 3 c.c is enough. This is *vaporised over hot water in the usual way; a very light* anæsthesia is induced in some sixty seconds, and the ether

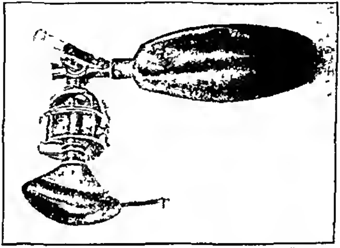


FIG 54 —Clover's inhaler adapted for the ethyl chloride-ether sequence.

can then be turned on at a much quicker rate than if the induction be conducted by the drug alone.

The gas-ether and ethyl chloride-ether sequences are most useful methods They are quick, safe, and powerful.

Either may be used as "single dose" anæsthetics, the ether being pushed quickly up to "full" and the inhaler then withdrawn If, however, no access to the mouth is required by the surgeon, ether anæsthesia may, by occasional breaths of fresh air, be prolonged for as long as desired

## CHAPTER XVIII

## THE ACCIDENTS OF ANÆSTHESIA

THE minor difficulties of anæsthesia have already been dealt with, and if the instructions already given, particularly in Chapter III, are faithfully carried out, incidents of real danger will rarely occur The soundest knowledge and the most conscientious care will however never entirely rid anæsthesia of an element of danger to life The conditions now to be considered are —

(*A*) Vomiting.
(*B*) Failure of respiration
(*C*) Failure of circulation

### (*A*) VOMITING

This always exposes an unconscious patient to the danger of inhaling solid or fluid material into the larynx with resulting asphyxia If the patient be tided through that immediate difficulty he is liable to develop an inhalational pneumonia subsequently

A healthy patient properly prepared should not vomit during the induction stage nor during the progress of the operation If he does it means that the induction has been too slow, or that the administration has been intermittent, and the patient has been permitted to come to too light a level of anæsthesia during the operation

During emergency operations where the patient's stomach may be full of food the case is different Such

patients commonly vomit early in the induction stage and no skill can avert the incident

A patient suffering from intestinal obstruction or from generalised peritonitis has his stomach and intestines full of highly infective fluid Reverse peristalsis may set in merely as the result of the inhalation or later from handling the contents of the abdomen and the feculent fluid gushes up the œsophagus with little or no warning Since vomiting in these cases may occur even in deep anæsthesia when the cough reflex which is the normal sentry to the entrance of the larynx is abolished the dangers of insufflation are very real indeed The authors prefer to wash out the stomach before beginning to induce anæsthesia in these cases but some surgeons believe that the shock of this procedure outweighs the advantages

## Symptoms and Treatment of Vomiting

In ordinary cases vomiting is usually heralded by a definite train of symptoms Respiration becomes shallow the colour a little pale and the pulse rather small The pupil is often very contracted but remains active to light indicating that the alteration of respiration and circulation is not due to overdose

At the first appearance of such symptoms a brisk rub of the lips and thereafter an increase of the vapour strength of the anæsthetic will often avert the impending vomiting by deepening the anæsthesia but if the possibility of this complication has occurred to the anæsthetist too late for its prevention the head must be turned well to one side and the other shoulder slightly elevated by a pillow so that vomited material will fall out of the mouth at once When the actual act of vomiting is over

no time must be lost in mopping out the mouth and pressing on with the production of a deeper anæsthesia

### (B) RESPIRATORY DANGERS

These divide themselves into two groups —

#### (1) Mechanical

The respiratory movements continue, but the ingress and egress of air are blocked. As already explained on page 26, the respiratory movements may cease quite soon, even though the original trouble was a mechanical block. This persistence depends upon the continuance of activity in the respiratory centre, which usually responds to the stimulus of gathering $CO_2$, but will fail to do so if too deeply anæsthetised.

*The symptoms and preventive treatment* have been referred to at some length in Chapter III, and no further account of these is therefore necessary. *The treatment of a complete blockage* of the air passages which resist the measure there described, alone remain to be mentioned. Of these, the only two effective are *artificial respiration and tracheotomy* (or laryngotomy, if preferred by the surgeon). Forcible artificial respiration by the Sylvester method, with the mouth gagged open and the tongue held forward by the tongue forceps, is frequently successful in getting over even a complete block, but the last resort of opening the air passage by the knife must not be delayed until too late. In deciding such a point, considerable judgment is, of course, called for.

#### (2) Non-mechanical.—Respiratory Arrest

This is usually seen in conjunction with a serious failure of the circulation caused by overdosage. Ex-

ceptionally, some act of the surgeon sets up a reflex inhibition of the respiratory centre, the circulation is at the same time depressed, but to a varying degree The cardinal *symptom* is arrest of all respiratory effort The *treatment* is best dealt with under the heading of circulatory failure

The student is also here reminded of what has previously been said as to the rapidity with which the respiratory centre succumbs to serious anoxæmia

### (*C*) CIRCULATORY FAILURE OR SYNCOPE

By the term syncope, we mean a more or less sudden failure of the cardiac pump, as opposed to the form of circulatory failure seen in surgical shock, where the condition arises gradually, and is not cardiac in origin (*see* Chapter II)

Syncope occurs under varying conditions which may for descriptive purposes be divided into four classes It is not however, always possible to decide with certainty into which class an individual case should be placed

The *symptoms* common to all classes of syncope are —

(*a*) Pallor, and loss of all tone in the muscles noticeably those of expression The pulse is weak or imperceptible

(*b*) Cessation of respiration

(*c*) Dilatation of the pupil, which ceases to react to light

The four classes above mentioned are as follows —

#### (A) PRIMARY SYNCOPE

This is peculiar to chloroform With no other anæsthetic is it seen at any rate in the healthy subject It arises during the induction period and is not necessarily preceded by any respiratory difficulty There is one big

inspiratory gasp sudden and extreme pallor and the pupil goes out to the rim in a few seconds The only reasonable explanation of such an incident is the occurrence of vagal inhibition (*see* page 155) Its prevention therefore is a matter of the avoidance of a high percentage of chloroform

### (B) Secondary Syncope

This term is applied to a collapse arising as a secondary result of embarrassed respiration Though not peculiar to chloroform it is far more common with that drug than with any other The most common time for the accident is towards the end of the induction period The patient has probably been struggling has clenched the jaws and developed mechanical asphyxia Violent inspiratory efforts are still being made and considerable cyanosis develops Either at the very moment when the respiratory difficulty is overcome or while it still persists the colour suddenly alters from blue to white and the other symptoms of syncope rapidly appear The exact period required to transform a blue struggling patient with heaving chest into one with pallid face and motionless chest and limbs varies greatly for reasons furnished below

The most reasonable explanation offered of such an accident is that given by Leonard Hill The attempts to inspire through an air way mechanically blocked cause an immense strain upon the heart muscle The flow of blood in the lung capillary is hindered and the right side of the heart becomes over-distended with blood Its musculature is further damaged by the fact that the blood in the coronary vessels is deficient in oxygen and that a considerable dose of anæsthetic has already been absorbed There is the further fact not mentioned by

Hill that during the whole period of asphyxia the peripheral resistance is rising from vaso constriction Under circumstances such as these it is obvious that *any* heart must ultimately succumb *no matter what anæsthetic is in use* It is also obvious that with chloroform and ethyl chloride which are themselves heart poisons secondary syncope will happen much more readily than with ether or nitrous oxide which are not and that a heart with diseased musculature will fail quicker than a healthy organ

Secondary syncope is almost certainly the commonest fatal accident of anæsthesia The reason why this fact is not more widely recognised arises from the natural instinct of any one who has suffered the misery and ignominy of causing a death under an anæsthetic, to attribute it to some cause beyond human control The *essential* cause of secondary syncope is failure to maintain a free air way which cannot be styled unavoidable Two consolations may however, honestly be offered to the person who has acted as anæsthetist in a case of secondary syncope Firstly it is in certain types of cases very difficult indeed to maintain a free air way, and secondly, a heart with muscle degenerated from fatty or other changes may give out after very little respiratory embarrassment

### Syncope from Overdose

This is a more gradual affair than the two foregoing, and has been sufficiently dealt with in the chapter devoted to the Stages of Anæsthesia (*see* page 52)

### (C) Reflex Syncope

Exceptionally a patient not overdosed with anæsthetic, and not suffering from any mechanical obstruction to

respiration, has a sudden attack of syncope during the progress of the operation We here exclude patients who are suffering from surgical shock, the condition arises too rapidly for such an explanation to be accepted Much speculation has been expended upon these cases One view is that some procedure of the surgeon has set up a reflex inhibition of the heart through the vagus, another, that the reflex has taken the form of sudden vasomotor paresis Levy * ascribes the condition to cardiac fibrillation, and agrees with the older surgeons who stoutly maintained that reflex syncope could not arise if the patient were properly under, and that it was in the practice of those anæsthetists who were afraid of pushing the anæsthetic sufficiently, that such accidents occurred Our own belief is that a *very* light chloroform anæsthesia does pre-dispose to this accident, but that it may occur also at a deep, the very deepest possible level With an anæsthetic other than chloroform, it is extremely rare, one case, however, occurring under closed-ether was privately reported to us

## TREATMENT OF SYNCOPE

This must be speedy to be of any avail The following are the points upon which to concentrate —

(a) *Withdraw the anæsthetic*

(b) Make sure that the *air way is free*

(c) Commence the intra pharyngeal administration of oxygen

(d) *Lowering of the head and shoulders*, best done by

* Levy does not accept vagal inhibition as the explanation of any sudden chloroform syncope nor does he seem to attribute as much importance as do most other authorities to obstructed respiration as a cause of secondary syncope

tilting the whole table as if for the Trendelenberg position, should be promptly carried out

(e) Begin *artificial respiration* by Sylvester's method, the movement of *expiration* being first performed (*see* Fig 55)

The lowering of the head attracts more blood to the

Fig 55 —Artificial respiration by Sylvester's method—Expiration

carotid artery and raises the blood pressure of the main vessel and its cerebral branches (*see* Fig 41) It must, however be remembered that it will also tend to empty the blood in the veins of the lower extremities and abdomen into the right side of the heart and cases in which marked cyanosis has preceded pallor are probably suffering already from engorgement and dilatation of the right hear *The tilting of the table should in such cases be very*

moderate in degree, and should not be persisted in if it seems to do no good In no case, indeed should the tilting be extreme An angle of more than 15° or 20° is as likely to do harm as good

(*f*) Hot cloths may be placed over the precordial region, care being taken not to burn the skin

FIG 55A —Artificial respiration by Sylvester's method—Inspiration

(*g*) The only *drugs* likely to be of any avail are atropine and strychnine, the former being used with the idea of paralysing the terminations of the vagus in the heart muscle, the latter as a cardiac tonic and a stimulant to the respiratory centre Some authorities have recommended the injection of atropine by a long needle passed into the heart muscle, but most are content to give either or both

drugs hypodermically Really to paralyse the vagus, a very large dose of atropine is required—about $\frac{1}{30}$ gr Strychnine should be given in a dose of $\frac{1}{50}$–$\frac{1}{40}$ gr

(*h*) In cases where the right heart has certainly been over-distended, the expedient of venesection has been tried Some six ounces may be withdrawn from the external jugular or one of the veins of the arm

(*i*) As a last *resort*, *the heart should be massaged* The most practicable route is to open the abdomen (if not already done), pass one hand under the left side of the vault of the diaphragm, placing the other hand over the precordial region Bost and Neve go a stage further, and incise the diaphragm close to its costal attachment so as to permit the hand to pass into the chest and grasp the heart outside the pericardium Between the two hands, the heart can first be thoroughly compressed to empty its presumably flaccid and over-distended cavities, and then lightly massaged Several cases of recovery under this measure are on record Throughout the period of massage artificial respiration must be maintained, as it is of little value to propel by manipulation highly venous blood through the coronary vessels An excellent means to maintain aeration of the lungs is to pass the catheter of the intratracheal apparatus, and propel down it a stream of oxygen at a low pressure Levy emphasises that if a fair chance is to be given to cardiac massage, it must be given before the central nervous system has been hopelessly damaged by the continued anoxæmia necessarily associated with stasis of the circulation However perfectly the aeration of the alveoli is maintained by artificial means, the central nervous system must starve for oxygen if the circulation has ceased and the resisting powers of nerve cells to this state of affairs will not hold out for long

## STATUS LYMPHATICUS

Before leaving the subject of accidents it may be well to allude to this condition which is also known as status thymicus and as lymphatism

It is met with mostly in the young the commonest ages probably being five to fifteen years Certain pathological conditions have been found in fatal cases of which the most important are an enlargement of the thymus gland, of various lymph glands and of the tonsils, including the naso pharyngeal tonsil (adenoids) The heart muscle is frequently degenerated Of the cause of these abnormalities we are as yet in doubt There is some reason to believe that the condition tends to disappear with advancing years if the subject survive Dr Kemp (*Canadian Med Assoc Journal*, November 1933) has advanced a new theory for the causation His view is that the primary cause is dysfunction of the thyroid from which arises acute adrenal insufficiency, the immediate cause of the syncope exhibited in status lymphaticus The enlargement of thymus and lymphatic glands is also attributed to the thyroid deficiency

The most outstanding clinical fact in connection with the disease is its tendency to cause sudden death on very little provocation A fright, a sudden exertion, and, above all, an anaesthetic may cause sudden and fatal syncope

### DIAGNOSIS

Suspicion that the disease is present may be aroused in several ways The presence of enlarged tonsils and adenoids, combined with general enlargement of lymph glands from no obvious cause and a tendency to faint, make a very suggestive picture "Night crowing" (a

sudden attack of laryngeal spasm, occurring at night and often repeated at intervals) also raises grave doubt The diagnosis can only be established with certainty by an X-ray photograph, when the great enlargement of the thymus may be seen in the upper part of the chest

### Anæsthetics in Status Lymphaticus

Too frequently the condition has never been suspected, and a *fatality occurs from sudden syncope*, usually during the induction period, but occasionally during the progress of the operation It would, however, be fallacious to suppose that an anæsthetic is necessarily fatal even to an undoubted case If the drug (preferably ether) be given with great care, and the operation done carefully at a level of anæsthesia neither too light nor too deep, there is every reason to believe that the danger can be, and often is, successfully averted

At the same time, it must be understood that in a known case, operation should always be avoided or deferred if possible Dr Kemp's theory as to causation has opened up other lines of treatment to which he refers *e g* the use of suprarenal cortex, thyroid extract, and iodine

## CHAPTER XIX

# THE SEQUELÆ OF ANÆSTHESIA

## RESPIRATORY SYSTEM

AFTER operations performed under any form of anæsthesia even spinal there is always a possibility of pneumonia or bronchitis The anæsthetic itself is not always to blame The patient has suffered trauma and is confined to bed and may develop a hypostatic pneumonia just as a person who has suffered from a fractured thigh so commonly does even though he has had no anæsthetic at all

It is probable that organisms capable under certain circumstances of causing inflammatory disease of the respiratory tract are present in a large proportion of apparently healthy people Pneumococci and strepto cocci of varying strains *may be grown from nasal or* pharyngeal secretions of patients who suffer from catarrh of these regions and may reappear upon slight provo cation even when prolonged treatment had apparently banished them permanently All that is required to start an acute infection of lungs or bronchi is some factor that depresses vitality and lowers body resistance to the organism and it has long been recognised that such a factor is inevitably furnished by a surgical operation under whatever form of anæsthesia it may be performed

The whole subject was exhaustively reviewed in the

Anæsthetic Section of the annual meeting of the British Medical Association in 1922 * Founding largely upon that discussion and also upon other sources of information we may summarise the present day opinion on the subject as follows —

(*a*) The post-operative morbidity rate in respect of acute inflammatory disease of the respiratory tract is broadly 4 per cent if estimated in a long series of unselected cases The death rate is difficult to fix with accuracy It is certainly small, perhaps about ·2 per cent

(*b*) The greatest factor at issue in any individual case is the nature of the operation In abdominal section cases, particularly where the incision is placed high up, there is a tendency to post operative paresis of the diaphragm, respiration being carried out largely by the action of the upper part of the chest only A basal pneumonia is thus not unlikely

(*c*) Ether is an irritant to the respiratory tract, and bronchitis is perhaps more common after its use than after that of chloroform The contention of the older authorities that ether was the sole or even the greatest *cause* of post operative bronchitis and that the use of chloroform is therefore obligatory to prevent its occurrence is, however, no longer tenable

(*d*) Exposure to chill before, during, or after operation greatly increases the patient's risk

(*e*) Respiratory sequelæ are more common in the winter than in the summer

(*f*) The presence in the mouth or throat of active infection (*e g* an acute naso pharyngitis, a septic condition

* The authors desire to express their indebtedness for the information rendered available in the opening paper in this discussion by Dr D Lamb of Glasgow

of the teeth or gums, a foul malignant ulcer on the tongue) constitutes a great danger, particularly if the operation itself be in the mouth, the septic infection being very likely to be inhaled into the lung and to cause trouble afterwards

(*g*) Excessive smoking, particularly of cigarettes adds to the risk of respiratory sequelæ

For the prevention of post anæsthetic pneumonia, the authors offer the following tentative suggestions —

(*a*) See that the skin is kept covered up as much as possible during the operation, and that the patient is not exposed to draughts during or after it Rooms can and should be, well ventilated without cold draughts

(*b*) If a patient has an acute or sub acute naso pharyngeal catarrh or other source of infection in the mouth, treat it as fully as possible before operation by sprays and gargles It may even be wise to immunise the patient by an autogenous vaccine

(*c*) Do not use ether to patients who suffer or recently have suffered from such conditions

(*d*) Give a hypodermic of atropine before operation as a routine, or morphia and atropine

(*e*) In so far as possible, let the patient's shoulders and head be raised by pillows during the early hours of convalescence

(*f*) Lastly, remember that while no care will absolutely banish these dangerous sequelæ from our practice, the greater care and skill shown by the anæsthetist, the less bronchitis and pneumonia will appear among his patients As regards ether, the authors believe that it is the strength of vapour used, more than the duration of the anæsthesia which counts It is for that, among other reasons that we have for the induction period no hesitation in recommending a method whereby a small part of the requisite

ether strength is replaced by chloroform or ethyl chloride

## VOMITING

The amount of vomiting which is to be regarded as normal after the patient has been returned to bed is difficult to express statistically, for what one observer would call severe vomiting would be styled by another a little sickness Dr G F R Smith, of Liverpool, has recently given some figures Working in a special hospital devoted to women s diseases only, he found that of 441 cases no less than 359 were not sick at all Of the remaining 91 52 only brought up a little mucus once or twice directly after return to bed 17 vomited several times but were comfortable within six hours of operation, and 32 continued to vomit for periods varying from ten hours to three days The same observer also published figures drawn from a general hospital where the patients would be of both sexes and where many of the anæsthetics were given by students Here the total vomiting rate was twice as high as in the other series

Of all anæsthetics nitrous oxide and oxygen gives so far as can be ascertained the least trouble as regards after vomiting but one of us met with one case who had asked for the method as he had had so much trouble in this respect with a previous etherisation and who was after his gas oxygen very sick indeed for twenty four hours It must be remarked that the administration had lasted over an hour and a half but the operation had not been severe in itself This must however, be regarded as quite exceptional in the main very little vomiting is caused by gas oxygen

As between chloroform and the various methods of

administering ether, it is hardly possible to lay down definite rules as to which causes the least after-vomiting. Much, indeed probably most, depends upon the skill of the administrator and the care which he exercises to minimise the amounts given, but in the hands of most administrators of average skill, it will be found that open-ether preceded by atropine or atropine and morphia (*see* page 60) will give the best results.

When vomiting is prolonged for twenty-four hours, or indeed for twelve hours in some cases, the question must always arise as to whether the cause is, indeed, purely anæsthetic, or whether some surgical condition may not be present. Gastric and intestinal stasis is always a possibility after abdominal section, and must be taken into account when considering a case. Discussion of the differential diagnosis would take us too far outside our subject.

### Prevention and Treatment

The adoption of open-ether or nitrous oxide and oxygen preceded by basal narcosis and due skill and thought on the part of the anæsthetist, combined with proper preparation of the patient, are the only means of prevention at our command.

The raised position of the head and shoulders during the recovery stage undoubtedly tends to reduce the nuisance. It is a vexed question whether to give or to withhold fluids after operation—and this matter is, of course, in the hands of the surgeon, not the anæsthetist. In certain cases, the authors believe that it is worth while trying the effect of a cup of fresh tea with very little sugar or milk. Even if rejected in a few moments, the astringent effect of the infusion seems to soothe the gastric mucous membrane, and give relief. Bicarbonate of soda,

in doses of one dram dissolved in a little water, is sometimes helpful

## POST-OPERATIVE ACIDOSIS

(Synonyms—Delayed Chloroform Poisoning—Post-operative Ketosis)

In a limited number of cases post-operative emesis assumes a grave type, and definitely threatens life Such cases began to be studied in the early part of this century, and though our knowledge of the condition is still incomplete, the student should be acquainted with the present views held upon the subject

Clinically, the earliest symptom to raise suspicion is the reappearance of vomiting at a time when one would expect such trouble to have abated, usually twenty four or thirty six hours after operation Within a few hours, the nature of the vomit changes from the usual bilious stomach contents, and shows obvious evidence of the presence of *altered blood* The pulse and temperature begin to rise, the countenance assumes an anxious look A trace of jaundice is usually present The nervous system becomes affected as shown first in restlessness, and later, delirium Every degree of this condition is possible, but a very large proportion of recognisable cases pass into coma and death supervenes within a few days, sometimes less

Investigation into such cases has shown that the essential underlying condition is an acidosis closely allied to that seen in diabetic coma The breath has the peculiar sweetish aroma of acetone, and acetone, diacetic acid, and B oxybutyric acid successively appear in the urine

Post mortem, the most striking change found is a

profound fatty degeneration of the liver, the cells of which are disintegrated as in acute yellow atrophy

It is obvious from the foregoing that there is present a very remarkable abnormality of metabolism Mr Rendle Short, in his admirable book, *The New Physiology in Surgical and General Practice*, gives the following explanation of the condition * —

"The physiological process of dealing with fat is to resolve it into carbon dioxide and water If we make a pound of fat into tallow candles and burn it, we shall obtain carbon dioxide and water and a certain amount of heat will be evolved If the pound of fat is eaten and absorbed by a man or an animal, it will be burnt to the same end products, and the same amount of heat will be given out But in certain circumstances, an abnormal † mode of breaking down is followed, and there are produced first B oxybutric acid, then diacetic acid, and finally acetone If this takes place on a large scale, the conversion into acetone fails to keep pace with the production of acids Therefore first acetone appears in the urine, then diacetic acid, and finally oxybutric acid, the last may rise rapidly to an enormous figure 30, 50, or even 180 grams may be passed daily"

Later in the same chapter, Short propounds the question as to what are the special circumstances in which the breaking down of fat deviates from its normal course, and follows this dangerous route The answer is, he says, quite definite and decisive When the tissues are unable to obtain sugar from the blood, fat is broken down *via* these dangerous acids to acetone, instead of to carbon dioxide and water

* In his last edition Mr Short has altered the wording but not the sense of the remarks quoted

† Prof Maclean would term it "incomplete" rather than "abnormal"

Such an inability on the part of the tissues to obtain sugar arises under several conditions —

(a) In diabetes where sugar though freely present in the blood cannot for some reason still not clearly known be assimilated by the tissues

(b) In poisoning by salicylates

(c) In starvation for obvious reasons The supply of sugar from the liver has been used up and the patient living on his own fats breaks them up abnormally

(d) In post anæsthetic poisoning for reasons which are at present not clearly ascertained

Upon the theoretical side it is therefore not possible to say more than that anæsthetics sometimes initiate this abnormal metabolic process To the question as to why and how they do so we can as yet give no certain answer That the liver is the seat of very profound changes is beyond doubt and we are probably not far wrong in taking the degrees of such changes as the measure of the gravity of any particular case Moreover it is clear that the same factors which increase the frequency and severity of ketosis are the very ones which have been shown to produce changes in the liver For instance Desmarest and Lascombes in 1921 showed that both ether and chloroform produced marked cholæmia which took five to six days to disappear while nitrous oxide and oxygen had no such effect as this combination produced no damage in the liver cells But it would probably be going too far to regard post-operative acidosis as a disease arising in and solely as a result of disease of the liver

Upon the practical side we can however speak much more definitely Ketosis follows the use of ether very rarely indeed after nitrous oxide it is unknown. Chloroform has been the drug used in almost every recorded case while ethyl chloride has been responsible in a few

isolated instances Young children are much more prone to suffer than adults though one of us had a fatal case in a lady well over forty years of age he has also seen a case very nearly fatal in a soldier aged twenty This man was a week after recovery from acidosis anæsthetised for half an hour with nitrous oxide and oxygen without exhibiting any signs of a return of his dangerous condition Anæsthesia repeated in the same subject after a short interval is more prone to start the process than a first inhalation Lastly acute sepsis particularly in the young is notorious for its liability to be followed by ketosis

## Prevention and Treatment

The obvious moral of the foregoing is that chloroform * should not be administered to patients suffering from acute sepsis particularly if they be very young Indeed so common is a mild degree of acidosis among children some surgeons consider there is a definite risk in giving chloroform to them at all unless special precautions are taken Chief among these are regular dosage for a day or two before operation with considerable doses of bicarbonate of soda and sugar which is a routine measure in some hospitals (*see* page 59 and also Appendix III) Prof Maclean in a recent paper read at the Anæsthetic Section of the Royal Society of Medicine gave an excellent summary of the present state of our knowledge of post-operative ketosis In his opinion there is neither practical nor theoretical justification for giving alkalis the only remedy either preventive or curative being sugar While the condemnation of alkalis may as yet not be generally

* Avertin has also been found to produce toxic effects on the liver It should not be used in combination with chloroform

accepted, there can be no question that the additional sugar is essential

Sugar must be introduced into the blood by some means If the vomiting is not too persistent, it may suffice to give it orally, in more severe cases it may be given in an enema The most certain and rapid method is to give an intravenous injection of glucose in saline solution

These measures, combined with warmth and ample fluids by mouth or rectum, will often save life, but to be of any value they must be begun early Fulminating cases occur which succumb rapidly in spite of treatment

### Insulin

The introduction to medicine of this new pancreatic preparation has of course, profoundly modified the outlook for sufferers from ketosis, as seen in true diabetes, and its success in that field raised high hopes that we might by its means save life also in the same condition occurring in non-diabetics Later work has, however, thrown doubt on the realisation of this hope, and in the paper already referred to, Prof Maclean urged that in post-operative ketosis we should pin our faith to the treatment by sugar For alkali, as already stated he had no regard at all and while not condemning further trial of insulin with the sugar, he plainly had no great expectation of benefit from its use

## CHAPTER XX

## POSTURE OF THE PATIENT

The position in which the patient is lying is of as much importance to the anæsthetist as to the surgeon. It is for the surgeon to say what he wants and for the anæsthetist to realise how his own work will be thereby affected.

### DORSAL DECUBITUS

This is the ordinary position and calls for no extended comment. The pillows must be so arranged that at no spot is the body acutely flexed or extended. Abdomen, thorax, neck, and head must all be roughly in a straight line.

Deep-chested subjects require a higher pillow than those with shallow chests, otherwise the neck is bent back and respiration obstructed.

The arms should be extended so that the hands can be slipped under the buttocks and retained there by the body weight. An arm which is allowed to hang over the side of the table is likely to show next day and for many months afterwards, the condition of drop-wrist from musculo spiral paralysis, the nerve having been compressed between the edge of the table and the humerus. One case has recently come to the authors' notice where the ulnar nerve was similarly affected.

### FACE-DOWN POSITION

This is an awkward position for the anæsthetist; there being a general tendency to respiratory embarrass-

ment Put a pillow under the upper part of the thorax, leaving the lower part and the abdomen as free as possible Let the head project from the pillow, so that the face can be got at without undue rotation of the neck The intratracheal method is a great help

### LATERAL POSITION

This may be called for either with or without the addition of a sand bag or inflatable air pillow to push the loin upwards In either case there is a tendency for the upper shoulder to fall forwards, the position then assimilating itself to the face-down position This is best met by a support fixed to the table, upon which the upper arm may be rested Failing such a convenience, a sand bag may be pushed in to keep up the shoulder, or the assistance of a nurse may be required.

### THE TRENDELENBURG POSITION

Slight tilting of the head end of the table downwards is often useful in assisting the return of bowel into the abdomen in this position the patient usually takes the anæsthetic very well It must not be assumed until the third stage of anæsthesia is reached

For many gynæcological operations, however, the full Trendelenberg position is required Healthy subjects usually do quite well in it but stout persons not uncommonly show a good deal of cyanosis At the close of the operation it is essential to restore the table to the horizontal *slowly* the physics of the circulation are profoundly modified and if any serious degree of shock is present rapid return to normal may initiate a collapse

In the full position, the weight of the body should be

taken by metal supports attached to the table against which the shoulders may rest To hang the entire weight of the body upon the legs may cause a good deal of after-suffering to the patient

As a certain degree of respiratory embarrassment is inevitable, oxygen is a useful adjunct to anæsthesia

Fig 56 —Sitting up posture for operations on the neck

### THE SITTING-UP POSITION (*see* Fig 56)

The object of this position is to diminish venous engorgement and bleeding in operations requiring delicate dissection in the region of the neck Prof Alexis Thomson introduced the position into Edinburgh surgery the author was at first rather nervous of it, but has found that with proper precautions the patients do uncommonly

well Beyond all doubt the position is a great help to the work of the surgeon

Not every surgical table is capable of giving the full position without the use of many pillows and sand bags The headpiece of the table is tilted up at an angle of about 75° or even 80° and the patient pulled up so that the flexion of the body occurs in the lumbar not the dorsal spine A small sand pillow is placed behind the neck so as to produce slight extension Another heavier one is placed under the thighs to prevent the body slipping down A slight tilt downwards towards the head end may be given to the table as a whole with the same object

One should not in this position attempt to induce a deep chloroform anæsthesia Weak C E mixture at most but better simply open ether is the method of choice The induction is begun with the shoulders raised to a modified degree and the full position assumed in a light third stage anæsthesia

Intratracheal ether combined with this position is an ideal anæsthesia for the removal of goitre or extensive dissections in the neck for enlarged glands

### O'MALLEY'S POSITION FOR NASAL SURGERY (see Fig 57)

One of us became acquainted with this useful position while acting as Anæsthetist at the Royal Herbert Hospital Woolwich where the Nose and Throat Department was under the charge of Major O Malley F R C S Major O Malley was kind enough in a letter written by request to refresh his memory of the details

With the patient lying as shown in the photograph every part of the interior of the nose can be easily in spected by the surgeon the elevation of the head and shoulders prevents undue bleeding and such hæmorrhage

as does occur goes down the gullet, where it does no particular harm, instead of into the larynx The degree of flexion of the head upon the neck is not so extreme as to *interfere with respiration*

The details of O'Malley s procedure are as follows —

The interior of the nasal cavities are packed with gauze soaked in adrenalin and novocaine a quarter of an

Fi 57 —O Malley s posture for intra nasal surgery

hour before operation, and the patient receives a very small dose of morphia and atropine immediately before anæsthesia is induced given in this way it does not complicate the induction with chloroform to the same extent as if given earlier The patient lies with the top of the head level with the top of the table, and the head and shoulders (including the upper two-thirds of the shoulder blades) supported on the usual depth of pillow The head of the table is elevated to an angle of 45° Induction is by chloroform or mixture, a very light third

stage only is aimed at When it is attained the mouth is opened by a gag, and Phillip's Oral Air way inserted (*see* Fig 7) Strict oral respiration is essential to success If air is passing in and out of the nose, blood is spluttered all over the surgeon, seriously interfering with the harmony of the proceedings Junker's chloroform bottle is ready, and the end of the supply pipe is passed into one of the side holes in the air way

*A small sand pillow is slipped now behind the occiput* The gauze is removed from the nose, and the operation can be performed with great comfort

The circulation of the patient needs careful watching for the first minute or two, but thereafter there is usually no special cause for anxiety The area of operation is locally anæsthetised by the action of the novocaine and a light chloroform sleep only is required

O Malley was not the first to use for nasal surgery an elevated position of the head and shoulders, the credit for this lying with the late Dr de Prenderville, Anæsthetist to the London Throat Hospital, and with the surgeons with whom he worked, notably Mr Claude Woakes Dr Prenderville designed a chair somewhat similar to that used by dentists There was a head rest adjustable at several angles and heights, and a long support for the feet and legs, thus *securing stability He worked at a light* level of chloroform anæsthesia, with the cough reflex just present As a matter of fact also, he induced with nitrous oxide or ethyl chloride, following on with chloroform To O'Malley, however, would appear to be the credit for realising the advantage of securing complete oral respiration by the use of some such air way as Phillips', and of so arranging the sand pillow at the back of the head as to permit blood running down the naso-pharynx from the posterior nares, to find its way into the gullet instead of

the larynx The exact angle must be found; if the head is too much flexed on the neck, respiration tends to be hampered, if too little, the blood drops into the wrong orifice. The cough reflex is, of course, retained, but the patient should not need to use it It is the swallowing reflex of which he stands in need When O'Malley was at work the author remembers very vividly that two things were anathema the patient must not cough, for if he did it meant the sand pillow was in the wrong place, he must not breathe through his nose, and spray blood over the surgeon

That extra care is necessary in the administration of chloroform to the sitting-up patient, the authors would be the last to deny There is also the question referred to on page 158, of the dangers of the adrenalin-chloroform combination As already mentioned, surgeons now use the adrenalin *before* chloroform anæsthesia, not *during* its course, but one cannot rid one's mind of the possibility of a little pool of adrenalin solution lying in an odd corner of the nasal cavity, and being absorbed during the progress of the operation Having in view, however, the needs of the rhinologist and the many problems which his work always sets to the anæsthetist, we may well overlook the theoretical objections to the method, and think only of the very satisfactory results which can be achieved by O'Malley's method, provided always that the utmost care and skill be exhibited by the anæsthetist, and that mutual confidence and co-operation exist between him and the surgeon.

## CHAPTER XXI

### *ANÆSTHETICS IN LABOUR*

It will, no doubt, be well known to the student that Sir James Simpson established the place of chloroform as *the* anæsthetic in labour, and the author does not deny the vast blessings which his work has conferred upon parturient women Nonetheless, the position is at the present day not as it was in the days of Simpson or even in much later times A tradition was established that the pregnant or parturient woman had some special immunity to the action of chloroform This thesis can no longer be maintained If the drug is pushed to the stage of full surgical anæsthesia, its effects are in every way similar to those seen in other individuals, the supposed safety lies (1) in the fact that it is ordinarily used in minimal dosage, to produce a condition of analgesia solely, and (2) in the absence of the fear element, women in labour being in a state of mind to welcome the administration of an anæsthetic Given in this way, there appears to be little or no danger, as the stimulus of the pains does not seem to excite the cardiac fibrillation to which Levy has drawn attention (*see* page 157)

Many techniques have been suggested for the exhibition of chloroform as an analgesic or anodyne One is for a little of the drug to be poured on a piece of blotting paper placed in the bottom of a tumbler This the patient holds to her nose when the pain begins, as she loses consciousness of pain her hand drops down and the

administration is automatically interrupted Another method is to fix a Junker inhaler to the end of the bed the vulcanite facepiece being lightly strapped to the face The patient squeezes the bulb *herself* with the same automatic result as in the tumbler method During the later period say when the head is passing over the perinæum the physician must take charge and either by Junker or other method keep up a supply of weak chloroform vapour so as to secure continuous light sleep

In cases where the continuous method has to be adopted for a prolonged period there is likelihood of delaying the labour by reducing the activity of the uterine muscle Martin of Sheffield describes the combination of continuous chloroformisation with the hypodermic administration of pituitrin which by its well known action upon *unstriped muscle prevents the advent of uterine inertia*

## Chloroform Capsules

To meet the demand for painless labour even in those cases in which a midwife is in charge recourse has been taken to minimal safe doses of chloroform For this purpose capsules containing 15 minims of chloroform have been put on the market One of these is broken and the contents sprinkled on a towel which is then applied over the mouth and nose during the delivery of the head While this method provides reasonable safety in the great majority of cases and if the dose be kept down to the minimum there is always the risk if the labour be prolonged of several capsules being used and dangerous concentrations of chloroform arrived at Furthermore the handling of such a drug as chloroform by the inexperienced is to say the least of it open to question

## TWILIGHT SLEEP IN LABOUR

The object of this method is to enable a woman to pass through labour without either the consciousness or remembrance of pain Its advocates claim that with due care this can be effected in a large proportion of cases The drugs used are omnopon and scopolamine, or morphia and scopolamine The former combination being the most commonly used, *will be here described*, but the equivalent doses of morphia can be ascertained by reckoning $\frac{1}{4}$ of a grain of morphia as equal to $\frac{1}{3}$ of a grain of omnopon In all cases the drugs are administered hypodermically

The first injection is given as soon as it is certain that labour has begun The dosage must be adapted to the type and physique of the patient To a strong athletic primipara as much as $\frac{1}{2}$ gr omnopon and $\frac{1}{100}$ gr scopolamine should be given, to a less robust type, a smaller dose say $\frac{1}{3}$ gr omnopon and $\frac{1}{150}$ gr scopolamine

After the first injection the room is darkened and all noise suppressed as far as possible The patient is put to bed and told to go to sleep

The second injection is given from one to one and a half hours after the first, and consists of scopolamine only in doses of $\frac{1}{450}$ to $\frac{1}{200}$ gr The smaller dose is often quite sufficient

The great object of the method, as already mentioned, is to prevent any *remembrance* in the patient, of the pains, if upon recovery from the effects of the drugs she has no recollection whatever of having suffered, she is said to have been *amnesic* Osborne Greenwood, of Harrogate, thus describes a method of testing for the condition of amnesia —

"The method of applying *the test for amnesia* which I

use is as follows. Some object with which the patient is familiar is chosen, a convenient one being something from the infant's basket—a sponge, a comb—but any other, such as a key, or a penny, will do. The patient is gently roused, shown the object, and asked what it is. She will usually reply promptly, 'A sponge.' She is then allowed to fall asleep at once. About half an hour later she is again roused and asked, 'What did I show you a little while ago?' If she promptly replies, 'A sponge,' she is not yet amnesic; if she appears to make an effort to remember and finally does so, she is on the verge of amnesia; but if fully amnesic she will say she does not know or will give some perfectly irrelevant reply, or perhaps do so by a counter-question. We have now attained the object in view, and as the testing proceeds during the progress of the labour a repetition of the scopolamine is needed if the patient appears to be on the verge of remembering the object shown, or if she does just recollect it, but not unless. The following doses will vary in amount as in the case of the second one.'

In the average case the best results are obtained by using for the second and subsequent doses $\frac{1}{150}$ or $\frac{1}{200}$ gr. of scopolamine, which is usually found necessary every hour. This scheme must, of course, be checked by some such method as that above described, and the size of the dose adjusted as found necessary. The intervals of one hour appear, however, suitable for most cases. The dose of omnopon or morphia is not repeated. Some obstetricians add to each dose, or to each alternate dose, a small quantity of atropine, say $\frac{1}{100}$ gr. This tends to counteract the *slowing of respiration*, which is *often* so marked a symptom of this form of narcosis. The cyanosis which results from this diminished respiratory exchange is the most undesirable feature of the method. It affects

not only the mother, but also the new-born child, and is said by Hirschman to be at its height from two to two and a half hours after the first injection On this ground he advocates that if a labour is likely to be completed within this period the dosage should be reduced

There appear to be good grounds for stating that with omnopon scopolamine, the force and frequency of uterine contractions are not affected, indeed, upon the whole, labour tends to be somewhat accelerated On the other hand, with all its advantages, the method calls for so much attention and supervision that it is doubtful to what extent busy practitioners may be expected to utilise it Again, failures are not unknown, in which instead of sleep a condition not far removed from mania is produced No doubt further experience will show how these difficulties may be surmounted

## Other Anæsthetics in Labour

Provided the patient is prepared to face a slight addition to the expense there is nothing to prevent the use of nitrous oxide and oxygen throughout the painful stages of labour, and this combination has here its usual outstanding advantage of non toxicity The consumption of gases may, of course, be large if the labour lasts some hours Not less than 200 gallons of nitrous oxide and 60 gallons of oxygen should be available

The intermittent flow apparatus is particularly suitable for obstetrics as wastage of gases is largely avoided McKesson has devised an apparatus specially for anæs thesia in this field

Minnitt, of Liverpool, has recently introduced a gas air apparatus for analgesia in labour (*Proceedings of the Royal Society of Medicine* Vol XXVII, No 4) It is intended

to be used as a self-administered method, and the facepiece held on the face by the patient herself. By an ingenious

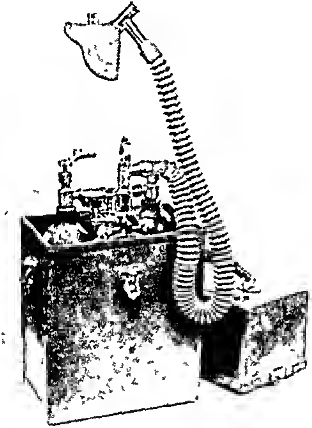


FIG. 58.—Minnitt's apparatus for analgesia in midwifery (portable model)

arrangement the gas-air mixture is delivered so long as the patient is able to hold the facepiece on. As the control

necessary for this disappears with muscular relaxation the gas supply is cut off and air alone respired The method is therefore a particularly safe one and is stated by Minnitt and others who have used it to be very efficient as an analgesic in normal labour The inventor emphasises that it is only intended for this purpose and not for purposes of anæsthesia *It is precluded for operations such as* version the application of forceps or extensive repair of perineum

The machine is economical in the amount of gas consumed about 35 to 40 gallons per hour

For the major operations of obstetrics chloroform should not be given unless definite bronchitis is present and nitrous oxide and oxygen are not available The shock of such an operation as a difficult version is very considerable and quite sufficient to call for ether rather than chloroform

## CHAPTER XXII

## CHOICE OF ANÆSTHETIC

In considering this matter, some repetition of points to which reference has already been made is inevitable Indeed, this chapter may be regarded as a revision of the whole subject

Before deciding upon drug and method suitable for the individual case, we must consider the age and sex, the physical type and temperament, the possible presence of some definite pathological condition and the nature and duration of the operation

In relation to this last point, we must remember that an anæsthesia must be adequate to the purpose of the surgeon, but that it is improper to incur more risk to life than is necessary For instance, an abdominal section case must be fully relaxed, and if in an individual case chloroform is the only drug which will give that effect, there need be no hesitation in using it On the other hand, if all that is required is the extraction of a tooth or the incision of an abscess, many other methods with a far smaller mortality are available, and in that group of cases, unfamiliarity with such anæsthetics as nitrous oxide or ' ethyl chloride and ether ' will not be held as a sufficient *defence if chloroform has been given with a fatal effect*

### NORMAL SUBJECTS

Let us take first the case of the healthy adult about to undergo a *major* operation For this, we unhesitatingly

choose some form of open-ether, either the "Perhalation" method described on page 124, or the warmed ether method of Shipway. In either case, a small dose of atropine or morphia and atropine (*see* page 132) must precede the inhalation The scope of gas-oxygen has been referred to on page 60.

If the operation be *brief*, we have a choice of methods. For the extraction of teeth, where access to the mouth is essential, the following table will help :—

| Anæsthetic Drug and Method | Duration of Available Anæsthesia, when given as "Single Dose" | Remarks. |
|---|---|---|
| Nitrous oxide | 30 to 40 seconds | |
| Nitrous oxide and oxygen | 40 to 50 seconds | |
| Ethyl chloride | 70 to 90 seconds | |
| Gas and ethyl chloride | 70 to 90 seconds | |
| Gas-oxygen and ethyl chloride | 70 to 90 seconds | |
| Gas and ether | Anything up to 2 to 5 minutes according to duration of inhalation | May cause after-vomiting |
| Ethyl chloride and ether | Anything up to 2 to 5 minutes according to duration of inhalation | May cause after-vomiting More portable |
| Nasal gas | 5 to 10 minutes (not a "single dose" anæsthetic) | Requires considerable practice to give well |
| Nasal gas and oxygen | No limit | Easier to give than above, but apparatus less easily transported |

In cases where access to the mouth is not required, and where it is therefore unnecessary to "charge up" the

patient with anæsthetic, we have also a choice which may be expressed tabularly —

| ANÆSTHETIC | REMARKS |
|---|---|
| Nitrous oxide | Apparatus simple short administration can be mastered easily A little more practice required for cases prolonged by admitting air Muscles not relaxed and patient may move when cut |
| Nitrous oxide and oxygen | Apparatus more complicated but short administrations present no great difficulty to the beginner Muscles not completely relaxed unless a little ether added |
| Gas and ether | Quick and safe anæsthetic Deep anæsthesia may be obtained if ether is pushed |
| Ethyl chloride and ether | The same More portable than above |

In this group of short operations special reference must be made to the *reduction of dislocations* Here two important features require notice The whole object of the proceeding is to relax muscles, and therefore nitrous oxide or gas oxygen is unsuitable Secondly, the tendency to reflex syncope just at the moment of reduction is very great For this reason, chloroform has here a painfully *high mortality rate*, *closed-ether, preceded* by gas or ethyl chloride, is undoubtedly the method of choice

## THE EXTREMES OF AGE

There is no doubt that chloroform has very special risks in quite young children, and that fatal overdose is readily produced If the drug be used at all, it should be

combined with ether in a mixture not stronger than one part chloroform to three parts ether, given on an open mask by a strictly "drop" method To many children it is possible to give ether alone, preceded, of course, by an adequate dose of atropine to mitigate the nuisance and danger of excessive excretion of mucus Where acute sepsis is present in children of any age, chloroform has peculiar dangers (*see* page 206 for an account of acidosis), and to such patients ether alone should be given if nitrous oxide and oxygen is not available Dr Ross Mackenzie of the Royal Hospital for Sick Children, Aberdeen, has had most admirable results with gas-oxygen, even with children of one year or less He uses, however, a proportion of oxygen much higher than is given to adults, and a special mask, described on page 104

Dr Mackenzie demonstrated his method in 1926 before a joint meeting of the Scottish Society of Anæsthetists, and of a group of American anæsthetists, with very impressive success The importance of his pioneer work on the subject is being now more appreciated, and it is probable that his recent paper on the subject will still further stimulate interest in it

Old people are, unless very feeble, best anæsthetised by a mixture of chloroform and ether Whatever anæsthetic be chosen, the utmost care must be taken to avoid cyanosis A cylinder of oxygen should be at hand from which to enrich the atmosphere breathed, by trickling the gas into the mouth through a rubber tube, and is a great safeguard in dealing with the old

## SEX

On the average, women take anæsthetics much better than men, being far less liable to jaw clenching and other

forms of mechanical asphyxia and showing less excitement during the induction stage In the female subject induction by open-ether requires very little assistance from C E mixture

## PHYSICAL TYPE AND TEMPERAMENT, AND HABITS OF LIFE

Heavily built muscular men are troublesome subjects Induction requires a rather strong vapour of ether if the open method is used there may be to the beginner much temptation to make use during the induction stage of C E mixture to an extent not contemplated in the description given of that method in Chapter XI it is therefore wise to induce either with closed-ether or with C E mixture as described in Chapter XVI and to change to the perhalation method only when full anæsthesia is attained

As regards alcoholics and excessive smokers these are well dealt with by the C E open-ether sequence Recourse may be made to the Ormsby inhaler as already explained on page 186 The reader is warned not to be deceived by the stout rosy face of the typical alcoholic He often looks a great deal stronger than he really is Many such are really feeble subjects although they shout and struggle no great addition to the usual vapour strength of anæsthetic is safe or required what is required is a little extra time Once fully under the robust appearance of the patient disappears and the fact that one is dealing with a rather broken constitution and a poor circulation is obvious

*In* a paper read before the Scottish Society of Anæsthetists in 1921 Johnston of Aberdeen pointed out that many of the abnormal phenomena noted under general

anæsthesia in alcoholics and also in those who habitually indulge in other noxious drugs such as morphia, arise essentially from defective oxygenation of the nervous system To such cases it is therefore always wise to administer an atmosphere enriched by oxygen from a cylinder of the gas which should always be available in an operating theatre

Reference has already been made to the fact that persons with defective nervous systems, neurotics, and especially epileptics, show persistence of some muscular movements for some time, and therefore require very careful watching

## SPECIAL OPERATIONS AND PATHOLOGICAL CONDITIONS IN THE PATIENT

These are of the utmost importance, but to consider each fully from the anæsthetic point of view would lead us into great detail The anæsthetist must acquaint himself with any abnormality present, and consider it carefully in the light of the general principles already explained The following very brief hints for selected cases and operations may, however, be found useful

### Upper Air Passages

*Artificial teeth* —Must be removed before inducing

*Tongue and jaw cases* —Intratracheal ether the best—failing that, rectal oil ether, or Shipway s inhaler

For cases in which much blood is likely to be shed into the mouth, and where intratracheal anæsthesia is not being used, the instrument shown in Fig 59 is of value It consists of an electrically driven pump and two bottles The current of air is drawn through the one

bottle, and a tube placed in the most dependent part of the buccal cavity sucks out the blood as it is effused.

As regards the other bottle (placed in the figure, in front of the suction bottle), the current of air passes from the pump towards the bottle, which is filled as to three-quarters of its capacity with ether. A tap at the head regulates the amount of air allowed to pass into the bottle, and a tube conveys the ether vapour to the mouth or nose of the patient.

*Nasal operations.*—If adrenalin is to be used, it must precede, not follow, chloroform—many fatalities have occurred from injecting or even packing with adrenalin *in light chloroform narcosis.* *Some surgeons object to* ether because of the bleeding, but this can be largely remedied by raising the head and shoulders, and by packing with adrenalin. Many surgeons prefer local to general anæsthesia.

*Nasal insufficiency.*—Don't allow a patient to continue to make ineffectual attempts to breathe through a narrow nose. Establish mouth breathing, or use Silk's tubes (*see* Fig. 8).

*Tonsils and adenoids.*—Each surgeon has his own preference as regards posture and anæsthetic. The technique usually followed in Edinburgh is to give ethyl chloride by the vapour method (*see* page 171). The mouth gag is placed in position between the teeth before the administration, but it is not opened up until the mask is removed. The tonsils are removed by the tonsillectome with the patient in the horizontal position and the face looking straight up. No pillow is used. For the removal of the adenoids the patient is pulled up the table and the head allowed to hang over the end in what is known as the Rose position. The patient is now turned on to the face and the blood allowed to pour out of the mouth

into a bucket placed ready at the end of the table The face is sponged well with cold water, and the clot in the nose squeezed out as far as possible As soon as signs of recovery are showing in the form of phonation and movement the patient is again turned on to the back,

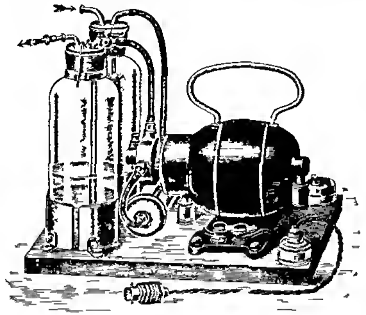


FIG 59 —Moseley s pump for sucking blood out of the mouth and propelling ether vapours

and is now propped up *into the sitting posture* The cold sponging of the face is continued, and the patient encouraged to cough and spit out any remaining clot Finally he is told to blow down his nose the face is cleaned and dried and the patient carried off to bed The cold sponging and the elevated position of the head and shoulders should before then have brought the bleeding

down practically to nil The whole process of induction operation and recovery should not consume more than five minutes

For dissection of tonsils a prolonged anaesthesia of a deeper nature is required A very satisfactory method is to induce with perhalation ether, to insert a Boyle Davis gag (Fig 60) in the third stage and to continue with ether from a Shipway apparatus delivered through the tube provided for the purpose in the tongue plate of the gag With this gag in position the head is dropped and very satisfactory access to the throat is made possible The operation is rendered very much easier if suction is available A suction pump of the type described (Fig 59 page 232) is of immense advantage

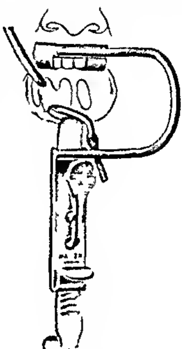


Fig 60—Davis Gag

*Tumours and inflammatory swellings obstructing respiration* —The use of closed methods is very liable to cause vascular engorgement and so to narrow the air way even more Place the patient in the position in which he breathes most easily which will usually be one of moderate elevation of the head and shoulders Use open or vapour ether or a mixture of ether and chloroform The surgeon should be prepared to perform tracheotomy and the necessary instruments should be ready A cylinder of oxygen should be at hand

Exophthalmic goitre is a condition which should be treated with more than ordinary respect by the anæsthetist The disturbed state of the circulation and nervous system of the patient makes the subject a bad risk Avertin seems to have an antagonistic action to thyroxin which renders it particularly adapted for toxic goitres Combined with gas-oxygen it makes the best anæsthetic for such cases Chloroform should never be used in a case of exophthalmic goitre

## CHEST

*Bronchitis and pneumonia* (*see* remarks in Chapter XIX)

*Emphysema and rigid chest wall*—Patients take anæsthetics badly, they cyanose quickly, the abdominal wall cannot be made either lax or quiet, since the patient s natural method of respiration is abdominal rather than thoracic Lastly, there is frequently a dilated heart with degenerate cardiac muscle, giving an abnormal tendency to secondary syncope Give a trickle of oxygen through a tube from a cylinder, don t be tempted to overdose with anæsthetic in the vain hope of securing ideal relaxation of the abdominal wall

*Empyæma*—Be careful a good many accidents have happened Use added oxygen, aim at an anæsthesia just deep enough to prevent straining, which might rupture the empyæma into the lung and drown him in his own pus Withdraw the anæsthetic as soon as the abscess is opened

*Phthisis*—Don t use closed-ether, it may start hæmorrhage—open-ether rarely does any harm unless the condition is very acute

Basal narcosis has been found useful in this group and should be followed by the minimum quantity of general anæsthetic

## CRANIAL SURGERY

Two very important points arise In the first place, the brain while wonderfully tolerant of changes in tension provided they are gradual, is very sensitive to sudden alteration in that respect Many cases come to table suffering from cerebral compression, and it is obvious that when the trephine hole has been completed, a sudden lowering of tension is inevitable and the respiratory centre is very liable to go out of action at this stage

Secondly, to secure access to certain parts of the brain, particularly the cerebellum, it is necessary to place the patient in the face-down position and (to make things worse) it may be necessary to flex the neck

The surgeon naturally desires to have as little bleeding as possible, and with this object there was formerly a tendency to choose chloroform as the anæsthetic enriching the atmosphere with oxygen Consideration of the two points mentioned above will, however, explain the fact that under this anæsthetic dangerous collapse was a frequent incident in cranial surgery

Avertin supplemented by intratracheal or rectal ether is now widely used

## ABDOMINAL SURGERY

This group embraces so much of the everyday work of the anæsthetist that its requirements have been already frequently mentioned A few special words may, however, here be added

The anæsthetist *must* give to the surgeon the most complete abdominal relaxation compatible with immediate safety and an ultimate recovery not too unpleasant

to the patient In simple cases this can be achieved quite easily, but we must acknowledge that in difficult subjects relaxation can only be attained at a price For the patient it means more depression and nausea for a period after the operation For the anæsthetist it means courage care and skill and added responsibility But it is to the ultimate success of the operation that both must look for their recompense, and no anæsthetist worth his salt will allow that to be imperilled by avoidable mechanical difficulties arising during the actual performance of the operation Once that point is made clear, we cannot be too emphatic as to the obligation which lies on the anæsthetist to spare his patient in every possible way Deep anæsthesia is only necessary as a rule during the opening and closing of the abdomen and during its manual exploration There are frequently prolonged periods during which little or no stimulus is being conveyed to the patient s brain and during such times a very light anæsthesia will suffice to keep him breathing quietly and evenly It is here that the skill and care of the good anæsthetist has its chance for by utilising these periods to the full much after suffering can be spared to the patient Anæsthesia is an art as well as a science

The upper abdomen is much more difficult to relax than the lower It is only in very fat persons or those with rigid chest walls (*vide supra*) that any trouble in that respect is liable to be seen for instance in a simple appendectomy

Lastly let the student remember the remarks made in Chapter III upon the subject of muscular rigidity as an early sign of anoxæmia A free air way is never more essential than in abdominal surgery and no pains to secure it can ever be wasted no matter how trifling the obstruction may appear

### Circulatory System

*High tension, arterio-sclerosis, and aneurysm.*—Avoid pure nitrous oxide; in severe cases C.E. mixture and oxygen is the safest.

*Heart.*—Well-compensated cases of *valvular disease* take chloroform or open-ether well, provided a free air way is maintained. Closed methods should be avoided. Cases of *myocardial disease* with dilated cavities present special dangers. Open ether with added oxygen meets the case better than any other anæsthetic. *Pericarditis*, both acute and chronic, has been found as the determining factor in many anæsthetic fatalities.

### Acute Infectious Disease

*Febrile patients* absorb anæsthetics very rapidly and therefore go under very quickly. Acute septic cases must not have chloroform or ethyl chloride (*see* page 208); nitrous oxide and oxygen is ideal, ether the next best. Patients who have suffered from acute infectious disease, especially diphtheria and influenza, may present some weakness of heart muscle for many months after the attack.

### Exhausted and Shocked Cases

Give nitrous oxide and oxygen if possible—failing that, ether. Closed ether sometimes does very well for the induction stage.

### Diabetes

Chloroform is wholly inadmissible. Give nitrous oxide and oxygen if possible. No method is devoid of the risk of exciting acidosis. The student is, however, referred to the remarks on page 210 upon the subject of insulin.

This preparation has the effect, temporary so far as we at present understand, of enabling the tissues again to assimilate sugar and break up fats to their normal end-products. If adequate time is available before operation for the proper study of the patient's metabolism, and for the amelioration in general condition which can now be obtained under insulin treatment, there would be every reason to hope that the diabetic person could take a general anæsthetic with risk no greater than usual.

### *Genito-urinary System*

*Kidneys.*—Avoid ether in acute or sub-acute nephritis; give it, however, for nephrectomy when the other kidney is sound.

*Bladder.*—Distending the bladder with lotion often causes reflex inhibition of respiration; if that happens, stop the anæsthetic, give artificial respiration, and ask the surgeon to get on with opening the bladder. *Morphia* usually arrests temporarily the secretion of urine; it should therefore not be given if chromo-cystoscopy or catheterisation of the ureters is contemplated.

*Prostatectomy cases* are often rather broken subjects; give a fairly deep anæsthesia until the shelling out of the prostate is begun; then be careful—the patient is breathing deeply as a rule, and can readily get an overdose. He will inevitably suffer a fair amount of shock: be ready to lower the table at the head end if any serious collapse occurs. Don't be shy of starting a little artificial respiration even though the natural function is not entirely abolished.

*Circumcision* usually causes a good deal of laryngeal spasm, especially in children. Don't try to abolish this by deepening the anæsthesia. You won't succeed unless

you nearly kill the patient. Rub the lips, and if very severe ask the surgeon to stop a minute until the crowing becomes less. Beware of reflex syncope.

*Castration.*—Always give ether or gas-oxygen. Castration and reduction of dislocation are the two commonest causes of reflex syncope under chloroform.

### Menstruation

It is customary to avoid the use of anæsthetics during the period, particularly during the first day or two of it. For this there is more than a sentimental reason, for doubtless the nervous system of the patient does not at such a time react normally. Should some emergency demand that the custom be broken, however, no real danger need be anticipated.

### Pregnancy

Save in the very early months, no special danger of causing premature parturition need be feared. Should the needs of the case call for the use of nitrous oxide, it is well, however, not to push cyanosis too far. During the later months we must remember that many women have an inherent tendency to develop bronchitis, and this must be borne in mind in choosing our anæsthetic.

*Indication for Local and Spinal Anæsthesia.*—The foregoing has been written in reference to general anæsthesia solely. In the following chapters the indications for spinal and local anæsthesia are discussed.

## CHAPTER XXIII

## LOCAL ANÆSTHESIA

By the term local anæsthesia, or more correctly *local analgesia*, is meant the loss of sensibility to painful stimuli without loss of general consciousness It may be induced in a considerable number of ways, but for practical purposes there are only four methods of value (1) by infiltration of the tissues to be operated upon by a solution of the drug, (2) by injecting the solution into or around the nerve trunks supplying the part, (3) by painting the solution on a mucous surface, and (4) by the application of intense cold The last method has only a limited application The method of injecting the anæsthetic into the blood vessels of the part is still in the experimental stage and is not to be recommended for general use

It is advisable first to consider the behaviour of the principal drugs which are employed

### COCAINE

This was the first drug to be widely used for the production of local anæsthesia It is an alkaloid occurring in the leaves of *Erythroxylon Coca* It is only slightly soluble in water—about 1 in 1300, but the hydrochloride of cocaine is freely soluble, and it is this salt that is commonly used for aqueous solutions The solutions do not keep well, and should be made up shortly before being used The drug is decomposed by boiling

ACTION.—When a solution of cocaine is injected into the tissues, the sensory nerve endings become anæsthetic over the area into which the drug penetrates, direct paralysis of the nerve terminals being produced. When it is injected into or around a nerve trunk it blocks the transmission of nerve impulses. When it is applied locally to a mucous membrane it produces, besides a loss of sensation, a feeling of constriction and a distinct pallor and contraction of the vessels, which point to a local action on the vessel walls. The drug is very frequently applied to the eye. There it produces not only local anæsthesia, but also contraction of the conjunctival vessels, and this is followed by dilatation of the pupil and often by partial loss of the power of accommodation.

COCAINE POISONING.—Certain patients show an idiosyncrasy to the action of cocaine, and the greatest care must be exercised in its use. Absorption of small quantities usually causes mental excitement. The patient becomes restless and garrulous, and a feeling of happiness may be produced, but in other cases the patient becomes anxious and confused. In some patients a small dose is followed by a calm languorous state, resembling that produced by morphia, but with less tendency to sleep. The pulse is accelerated, the respiration is quick and deep, and the pupils are dilated. When poisonous doses have been administered, the heart becomes extremely accelerated, powerful tonic or clonic convulsions supervene, the breathing becomes rapid and shallow, and may be finally arrested during a convulsion. In some cases a different set of symptoms are observed; fainting and collapse occur, and convulsive seizures are almost entirely absent. The heart is slow and weak, the respirations are slow and shallow, the skin is cyanotic and cold, and death takes

place from gradual arrest of respiration D M Greig has recently emphasised the danger attending the use of cocaine, and has reported a fatality from the use of a 5 per cent solution as a urethral injection

TREATMENT —The treatment consists in endeavouring to encourage the action of the heart by every possible means The patient is placed flat on his back, if he is not already in this position, hypodermic injections of ether and strychnine are administered and hot coffee given by the mouth, warmth is of great importance Artificial respiration is commenced if respiration begin to fail There is no specific antidote to cocaine

DOSAGE —The maximum dose of cocaine that can be given with safety is $\frac{3}{4}$ of a grain The amount of solution that may be employed depends upon the strength To make a 1 per cent solution, 1 gr of cocaine hydrochloride is dissolved in 110 minims of distilled water or half-strength normal saline, from these proportions the amount of cocaine in a given solution can be calculated It will be seen that the amount of cocaine solution, even with strengths as weak as $\frac{1}{2}$ or $\frac{1}{4}$ per cent, that can be used with safety is small and insufficient to anæsthetise an area of any great extent Owing to its toxicity cocaine has largely fallen out of use for the production of infiltration or regional anæsthesia, though it is still widely used in ophthalmic surgery and in the surgery of the ear, nose and throat

## NOVOCAINE

This drug is immensely superior to cocaine for ordinary surgical purposes *It is the hydrochloride of a synthetic base its chemical formula being $C_{13}H_{20}N_2O_2$ HCl It is*

soluble in water 1 in 1 and can be heated to 120° C without decomposition. Its solutions possess slight antiseptic properties, and are capable of repeated boiling without affecting their strength. They may be kept for several months without suffering any change in their action, a quality not possessed by many other anæsthetic agents.

The *toxicity* of novocaine is one fifth or one-seventh of that of cocaine. When used in conjunction with adrenalin its anæsthetic activity is equal to that of cocaine. When injected into the tissues it produces no irritant effects like certain other local anæsthetics, notably stovaine. For the production of local anæsthesia it is used in 1 per cent. solution with the addition of three or four minims of 1 in 1000 solution of adrenalin chloride to each ounce. Several ounces of this preparation may be used with the greatest safety.

Allen makes the following statement regarding this drug:— "After a rather extended experience including a large number of cases embracing the entire field of surgery, in which this agent has been almost exclusively used, we have failed to note a single case in which there has been any unpleasant local or constitutional action. We therefore feel thoroughly justified in unqualifiedly recommending it as the safest, most reliable, and satisfactory of any local anæsthetic agent yet introduced."

of decomposition It is the agent which is particularly suitable for spinal anæsthesia as fewer unpleasant effects have followed its use than that of any other drug

## STOVAINE

Stovaine is the hydrochloride of a synthetic compound of the benzoyl group It occurs as a white crystalline powder soluble in water 1 in 14 Its solutions withstand boiling but are decomposed when heated to 120° C Its action is the same as that of cocaine except that it is slightly less toxic and less powerful It has a distinct irritant effect locally When injected in dilute solution it produces a slight burning pain before anæsthesia appears and very often a distinct inflammatory reaction persists for some time after the operation It is therefore unsuited for local anæsthesia It has been widely used for the production of spinal anæsthesia especially by the French school but since its injurious effects on nerve tissues have become more apparent it has been less used than formerly

## ADRENALIN

Adrenalin is obtained as an extract from the supra renal glands of animals It is a greyish white powder slightly soluble in water and readily so in weak acids The usual preparation is a 1 in 1000 solution of adrenalin chloride in normal saline It contains 5 per cent of chloroform as a preservative The drawback to the animal extract is that the solution does not keep well decom position being indicated by a brownish colour Of late a synthetic preparation has been introduced which appears to have the same action and which can be sterilised by boiling

The action of the drug is to cause marked vaso-constriction by direct action on the vessel walls It has no analgesic action, and is used as an addition to solutions of anæsthetic drugs The advantages of its use are that the action of the anæsthetic is concentrated and prolonged, owing to the delay in absorption, and that the field of operation is rendered practically bloodless In large doses it may produce toxic symptoms in the form of palpitations and breathlessness, or even actual syncope, so that care is necessary in its use. For purposes of local anæsthesia, it is added to the solution of the anæsthetic drug in the strength of three drops to the ounce, and large injections of this dilute solution may be made without risk. At least twenty drops may be safely given

## INDUCTION OF LOCAL ANÆSTHESIA

Local anæsthesia may be induced by the use of anæsthetic drugs in three ways: (1) infiltration anæsthesia; (2) regional anæsthesia, and (3) by application to a mucous surface or to the surface of the eye.

INFILTRATION ANÆSTHESIA.—In this method anæsthesia is induced by injection of the drug directly into the tissues to be operated upon This method acts by paralysing the sensory nerve-endings Although the term anæsthesia is constantly used, it is, strictly speaking, an operative analgesia that is aimed at; it is a paralysis of the pain-conducting fibres, and not of those which conduct purely tactile sensations, the patient being often able to feel the contact of the fingers and instruments during the operation. True anæsthesia can be secured, but it is necessary to use considerably stronger solutions than those that are required for the production of analgesia.

SOLUTION OF THE DRUG.—Novocaine is a most satisfactory drug for infiltration anæsthesia. The strength for most purposes is ½ per cent, though some operators find ¼ per cent quite satisfactory. In specially sensitive parts such as the nose, throat or mouth 1 or even 2 per cent solutions may be preferable. Sufficient sodium chloride should be added to prevent osmosis of the solution into the tissue cells. The most satisfactory preparation is:—

| | |
|---|---|
| Novocaine | 0.25, 0.5, 1 or 2 (¼ to 2 per cent.) |
| Normal salt solution (half strength) | 100.0 (.45 per cent. NaCl) |

Adrenalin is added to the solution in the proportion of three drops of 1 in 1000 adrenalin chloride to the ounce, and as much as 6 ounces of this preparation may be safely given. The novocaine solution can be boiled before use, but the adrenalin must not be added until after boiling.

For private practice it is sometimes convenient to procure the novocaine in tablet form of definite strength combined with sodium chloride. These tablets are added to the necessary amount of water and the whole boiled. The adrenalin can then be added.

CHOICE OF SYRINGE.—The form of syringe commonly used for infiltration anæsthesia is the all-metal syringe. It ought to have a capacity of at least 10 c.c. The advantage of the all-metal syringe over glass syringes is that it can be safely sterilised by boiling and does not get broken. Between the syringe and the needle is a metal segment which is curved so that the needle is set at an obtuse angle to the syringe. This renders the infiltration of the tissues at the proper depth much easier. The needles should be of two sizes, one small and fine for

the dermal injection and the other longer—about 3 or 3½ inches—and of larger bore for the injection of the deeper tissues

Failing the syringe described, a 10 c c Record syringe will be found to be quite efficient if suitable needles can be obtained The syringe needles and glass measure for the solution should be boiled in plain water or normal saline, as soda interferes with the action of the drug

TECHNIQUE OF INJECTION —The needle is introduced into the subcutaneous tissue, and pushed on slowly to its full length, the fluid being injected as the needle advances The needle is then partly withdrawn, and pushed in a different direction so as to infiltrate a fresh area This procedure is repeated, and as wide an area as possible infiltrated from the one puncture The needle can then be completely withdrawn and introduced at a fresh point which has already been rendered analgesic The deeper tissues can nearly always be infiltrated from the surface but if large blood vessels traverse the region to be infiltrated, it may be necessary to defer the deeper injection until these have been exposed It is wise to infiltrate wide of the intended line of the incision since it is not possible to anticipate with certainty the extent of an operation until it has been commenced The secret of successful anæsthesia is to employ plenty of the solution and make the injection thorough

The skin over the area becomes blanched within a few minutes of the injection owing to the action of the adrenalin Anæsthesia is not usually complete until ten minutes have elapsed and the operation should not be commenced until it has been made certain by suitable tests that the anæsthesia is complete The duration of the anæsthesia is usually at least an hour and a half

It will be seen that the injection in the manner described above is entirely subcutaneous, the pain conducting nerves from the skin being caught up by the drug as they traverse the superficial fascia in the area infiltrated This method usually gives complete satisfaction, but discomfort can be minimised by commencing with an *intra dermal* injection so as to reduce the pain of the needle punctures to a minimum A fine needle is employed, the prick of which is practically painless If the skin at the selected point is pinched up between the finger and thumb, and held firmly this lessens its sensibility The needle is advanced beneath the epidermis with a quick but light thrust The injection into the substance of the skin causes a distinct wheal, which stands out from its surroundings like an urticarial wheal From this starting-point a long needle can be introduced into the deeper tissues without pain Additional intra-dermal wheals can be made at different points in the line of the incision by inserting the point of the long needle into the skin from underneath This procedure ensures that the patient shall feel no discomfort after the initial prick with the fine needle the long needle being re introduced as often as necessary through a fresh intra dermal wheal

Precautions —The most careful asepsis is essential throughout Infiltration with novocaine causes no interference with the healing of the wound, and although cases of sloughing of the tissues have been reported after its use, these are almost certainly due to infection of the wound Care must be exercised also to avoid injecting the drug into a vein When this accident takes place, the drug is carried at once into the general circulation, and may reach the higher nerve centres in such quantities as to produce serious toxic results The use of adrenalin

calls for special care and thoroughness in securing all bleeding points as after the effect of the adrenalin passes off even a slight ooze may increase and give rise to a hæmatoma which may jeopardise the healing of the wound

## REGIONAL ANÆSTHESIA

In this method of producing anæsthesia the sensory nerve paths are blocked by injecting the anæsthetic drug into or around a nerve trunk By this procedure complete anæsthesia is produced in the area of distribution of the nerve and the effect corresponds to a temporary physiological section of the nerve trunk A temporary motor paralysis is also produced in a mixed nerve

TECHNIQUE —The solution of the drug must be stronger than that employed for infiltration anæsthesia A 2 per cent solution of novocaine in half strength normal saline with the addition of adrenalin is employed The injection may be paraneural or intraneural

A *paraneural* injection is made by passing a needle through the tissues to the known position of a nerve trunk and injecting the anæsthetic around it The solution gradually diffuses into the nerve tissues and anæsthesia of the nerve is produced This method is open to the objection that unless the anæsthetic is accurately placed no anæsthesia will result and that in the case of certain nerves there is considerable risk of making the injection into a vein The latter risk can be avoided by using a glass barrelled syringe and applying a little suction before the injection is made if a vein has been pierced blood will enter the syringe

The *intraneural* method is more accurate but requires the expenditure of considerable additional time and

trouble, and is only employed where other methods of anæsthesia are not feasible The tissue over the nerve having been infiltrated, the nerve is exposed by open dissection It must not be pinched by forceps or other instruments as such manipulations cause severe pain referred to its peripheral distribution The injection should be made with the nerve lying in its bed by inserting a fine needle in the long axis of the nerve, first into the sheath which is infiltrated, and then into the nerve itself The infiltration of the nerve is continued until it presents a fusiform swelling and this may require from 5 to 15 minims of the solution Complete anæsthesia of its entire distribution usually results in from five to ten minutes

A third method of inducing regional anæsthesia—first recommended by Hackenbruch—which is worth mention is by the production of a ring of infiltration around a peripheral part such as a finger, or around and underneath a tumour By this means the nerve fibres are caught up by the anæsthetic and their conductivity interrupted as they enter the area to be operated upon In dealing with such conditions as a large lipoma, or an umbilical hernia it may be possible to avoid the use of an excessive amount of anæsthetic solution by employing this method

## METHODS OF APPLICATION OF INFILTRATION AND REGIONAL ANÆSTHESIA

It is sometimes stated that local anæsthesia should be limited to small and superficial operations, but with a knowledge of anatomy and of the correct technique, there are few operations which the surgeon cannot undertake with this form of anæsthesia If we remember that the mortality from the anæsthetic is practically nil, it is

obvious that it is often the duty of the operator to give the patient the choice of local anæsthesia. In urgent conditions in which the administration of a general anæsthetic would be attended with great danger, it is often a life-saving measure. Either infiltration or regional anæsthesia may be used alone; in some cases it is convenient to combine the two methods.

## OPERATIONS ON THE UPPER EXTREMITY

Regional anæsthesia is sometimes employed in operations on the upper extremity in conditions, such as diabetic gangrene or advanced cardiac disease, where a general anæsthetic is contra-indicated. In similar conditions in the lower extremity, spinal anæsthesia is usually preferred, though it is quite possible to anæsthetise the lower limb by blocking the sciatic, femoral, and lateral cutaneous nerves with a local anæsthetic. Crile lays great stress on the blocking of nerves with a local anæsthetic during operations on the limbs as a means of preventing shock, even where a general anæsthetic is being employed. The effect of the local anæsthetic is to prevent the impulses which produce shock from passing up to the higher centres. Only those methods which are applied to the upper extremity need special description.

branch of the third intercostal nerve sometimes crosses the axilla also, and reaches the medial side of the arm The posterior supraclavicular *nerves from the cervical* plexus descend for a short distance beyond the point of the shoulder Injection of the brachial plexus produces complete analgesia of the shoulder and entire arm, and is particularly suited to high amputations and dis articulations at the shoulder If the area supplied by the intercosto brachial is encroached upon, this can be anæsthetised by infiltration with a few drams of solution injected subcutaneously along the floor of the axilla from its lateral and posterior borders The posterior supraclavicular nerves may be caught up in the *superficial fascia* above *the clavicle at the site where the* injection of the plexus is made

METHOD —The injection may be intraneural or para neural The intraneural is made after exposing the plexus by an incision under infiltration anæsthesia from the junction of the middle and lower thirds of the sternomastoid to the union of the middle and lateral thirds of the clavicle *It is found lying on the scalenus medius* and each of its trunks is separately injected with a few drops of 5 per cent solution of novocaine containing a few drops of adrenalin to the ounce

The paraneural injection is less satisfactory, since the nerves are too large to be readily penetrated in effective quantities by the anæsthetic solution, and since there are numerous veins in the neighbourhood into which the solution may be accidentally injected with dangerous results

The injection is usually made above the clavicle In this region the plexus lies mainly above and to the lateral side of the third part of the subclavian artery, the lowest

trunk lying directly behind the vessel as it rests on the first rib The position of the artery is first localised with the finger by its pulsations and the skin and subcutaneous tissue infiltrated immediately above the mid point of the clavicle From this point a long fine needle unattached to the syringe is passed downwards backwards and medially in the direction of the second or third thoracic spine The distance to which the needle penetrates varies from 2 to 4 cm When the plexus is reached a slight radiating pain is felt down the distribution of the radial or median nerve At this point the needle is held stationary the syringe attached and the injection made The reason for not attaching the syringe earlier is that should the artery be entered blood will flow This accident is of little consequence the needle being withdrawn slightly and introduced a little more laterally About 10 c c of a 2 per cent solution of novocaine and adrenalin is injected the needle is then slightly withdrawn and a further 10 c c injected in the neighbourhood Anæsthesia occurs in from three to fifteen minutes

The individual nerves of the upper limb can be readily injected The *median* can be exposed at the bend of the elbow for an intraneural injection or a needle may be passed under the tendon of the palmaris longus at the wrist for a paraneural injection The *ulnar* can be easily reached as it lies on the posterior aspect of the medial epicondyle of the humerus for a paraneural or intraneural injection The *superficial radial* can be reached for a

The *medial antibrachial* (internal) *cutaneous* can be blocked on the front of elbow by a paraneural injection about half an inch medial to the biceps tendon, and the

FIG. 61 —Point at which the needle is introduced in paraneural injection of brachial plexus.

*lateral antibrachial cutaneous* (musculo-cutaneous) at a corresponding point on the other side of the tendon.

ANÆSTHESIA OF THE ARM BELOW THE ELBOW.—In operations below the elbow, in conditions in which a general anæsthesia is not permissible, as in diabetes,

nephritis or advanced cardiac disease a full anæsthesia can be obtained by intraneural injection of the median ulnar and radial (musculo spiral) nerves combined with paraneural injection of the medial and lateral antibrachial cutaneous The median and radial are each exposed by an incision under infiltration anæsthesia the radial being exposed in the *groove* between the brachialis and brachio radialis The infiltration to expose the median nerve usually blocks the anterior branch of the medial anti brachial cutaneous To make certain that the posterior branch is also anæsthetised it is advisable to inject a little anæsthetic solution over the front of the medial epicondyle The *intraneural injection* into the ulnar nerve can often be made without exposing it

ANÆSTHESIA OF FINGER —The paraneural method applied to the digital nerves at the root of the finger gives perfect results A circle of anæsthetic solution is first injected round the root of the finger The needle is then passed through the infiltrated skin on each side of the finger and a few drops of ½ per cent novocaine solution injected around the nerves Complete anæsthesia of the finger results in a few minutes

This method is especially suitable in the treatment of some forms of whitlow notably that at the nail fold It should not be used however in cases in which the in flammatory change extends as far as the root of the finger The inflammatory reaction appears to interfere with the action of the anæsthetic and the injection into an inflamed area may be exceedingly painful

IN THE LOWER LIMB injection of individual nerves is rarely employed as anæsthesia is easily obtained by the method of spinal analgesia The *lateral cutaneous* can be

injected as it lies immediately medial to the anterior superior iliac spine emerging from under cover of the inguinal ligament This procedure may be useful in obtaining skin grafts, the grafts being taken from the antero lateral aspect of the thigh Amputations in the middle third of the thigh have been performed by injecting the sciatic, the posterior cutaneous (small sciatic), the femoral (anterior crural), and the lateral cutaneous at the root of the limb The obturator nerve is difficult to find and anæsthetise in such cases Operations below the knee can be painlessly performed by this method of anæsthesia

### OPERATIONS ON THE NECK

TRACHEOTOMY —This operation is conveniently and safely performed under *infiltration anæsthesia* *The anæsthetic* solution is injected in the usual way in the line of the incision down to the trachea, but not into it, as the trachea itself is insensitive to pain

GOITRE —Local anæsthesia may be employed in almost any type of goitre, and is particularly indicated in many cases of toxic goitre The field of operation is mainly supplied by the cervical plexus, the superficial branches of which appear at the middle of the posterior border of the sterno mastoid muscle The nerves especially involved are the cutaneous colli and the anterior supraclavicular The thyroid gland itself is supplied by sympathetic fibres from the middle and inferior cervical ganglia, but the gland has very little sensibility to ordinary stimuli and may be cut across without previous infiltration J M Graham recommends that a pre-operative sedative be given in the form of **omnopon**, $\frac{1}{3}$ grain is given hypodermically one and a half hours before operation,

and one hour later, depending on the patient's reaction to the first dose, a second injection is given if necessary

A solution of $\frac{1}{2}$ per cent novocaine is employed, and in toxic cases it is advisable to omit the adrenalin The anæsthetic solution is injected along the line of the skin incision and about 20 c c are injected on each side at the middle of the posterior border of the sterno mastoid in order to block the cutaneous nerves which appear in this region The novocaine solution is then injected subcutaneously and underneath the preglandular muscles over the whole field of operation, *i e* up to the hyoid bone and down to the upper border of the sternum Special care is taken to introduce the solution around the upper pole and above the isthmus of the gland If the patient has not responded well to the *pre-operative sedative* and becomes restless and nervous during the operation, it may be necessary to supplement the anæsthesia with nitrous oxide and oxygen

The special advantages of local anæsthesia in goitre operations are that the operation must be done with gentleness and with the minimum of trauma, and that the patient can phonate at any stage of the operation if the integrity of the recurrent nerves requires to be decided After operations the patient can take fluids at once and there is a lessened tendency to respiratory complications (Graham)

## OPERATIONS ON THE THORAX

The greater part of the wall of the thorax is supplied by the intercostal nerves In front the supraclavicular nerves come down as far as the second intercostal space or sometimes as far as the nipple, and the lateral and medial anterior thoracic nerves supply the pectoral muscles, *sending a few twigs to the overlying skin* The long thoracic nerve extends down the side of the chest, supply-

ing the serratus anterior The intercostal nerves can be blocked in the region of the angles of the ribs and the supraclavicular by carrying a line of infiltration along the clavicle The anterior thoracic can be blocked by deeper injections In this way the greater part of the chest wall and the pleura can be anæsthetised

ACUTE EMPYEMA —This operation should almost always be performed under local anæsthesia Exhaustion from septic absorption and from the antecedent pneumonia or other disease with the dyspnœa from the pressure of the pus on the lung may render a general anæsthetic highly dangerous The method of producing local anæsthesia is simple and easily carried out A point is selected on the rib which is to be resected a short distance behind the line of the incision and an intra dermal injection made with a fine needle A long needle is then substituted and passed down to the upper border of the rib until it reaches the plane between the external and internal intercostal muscle the injection being continued lightly as it advances When the desired point is reached one or two drams of the solution are injected The needle is then slightly withdrawn and passed to the lower border of the rib to reach the same plane and the same procedure carried out The infiltration is then carried along the line of the incision or it may be made to pass obliquely upwards to the rib above and obliquely downwards to the rib below so as to catch up the nerves coming from behind into the area of operation The anæsthesia of soft parts bone and pleura is perfect after the above injection

## *OPERATIONS ON THE ABDOMEN*

The anterior abdominal wall including the anterior parietal peritoneum is supplied by the lower six inter

costal nerves the last thoracic nerve and the ilio hypo gastric and ilio inguinal nerves from the first lumbar It is a very interesting and important fact that, although the parietal peritoneum is exceedingly sensitive to touch and pain the visceral peritoneum and the viscera them selves are insensitive to ordinary stimulation When operations are performed under local anæsthesia of the abdominal wall, the viscera can be freely handled or incised without the patient experiencing the slightest discomfort, provided that the parietal peritoneum is not put upon the stretch by traction on the mesentery or other peritoneal attachment Thus the colon can be opened twenty four or forty eight hours after being brought outside the abdominal wall without any anæs thetic in the operation of colostomy Local anæsthesia is therefore, well adapted to cases in which a small amount of manipulation of the viscera is required, and where a general anæsthetic would be dangerous, as in grave cases of intestinal obstruction and in cases of carcinoma of the œsophagus with weakness and loss of flesh from starvation

GASTROSTOMY —This operation is commonly performed under local anæsthesia *and may be taken as an illustration* of the procedure employed The incision is made through the left rectus at the junction of its middle and lateral thirds and is about $2\frac{1}{2}$ or 3 inches long beginning immediately below the costal margin An intra dermal wheal is established at the middle of the proposed incision A long needle is entered at this point and passed first up wards and then downwards in the line of the incision infiltrating the subcutaneous fat as it goes The needle is then passed in through the anterior wall of the rectus sheath, this being easily recognised as a plane of decided

resistance The needle is advanced a little inside the sheath the injection being continued as it advances The same procedure is repeated at various points along the line of the incision The extra peritoneal fat may be infiltrated in the same way the posterior wall of the sheath being identified as a deeper plane of resistance and gently pierced This step may be deferred until the posterior wall of the sheath has been exposed The infiltration may be completed by forming a line of intra-dermal infiltration along the line of incision though this last step can often be omitted

The abdomen can then be opened painlessly The only step in the operation which may cause a little discomfort is the traction which may be necessary to bring the shrunken stomach down from under cover of the ribs The incision into the stomach is quite painless

GASTRO ENTEROSTOMY can be performed under local anæsthesia the only special step required being infiltration of the meso-colon before it is perforated

APPENDICECTOMY is not suitable as a rule for local anæsthesia If the cæcum is fixed or the appendix bound down by adhesions the traction necessary to bring the appendix to the surface causes considerable pain

In ACUTE OBSTRUCTION when the procedure of enterostomy has been decided upon owing to the gravity of the patient s condition local anæsthesia is often of great value The abdominal wall is infiltrated in the manner described and a distended loop of bowel brought to the surface and sutured to the parietal peritoneum A Paul s tube can then be introduced

Inguinal Hernia —Local anæsthesia is specially suited to cases of strangulated hernia, but it may be employed in the ordinary case It has the great merit of obviating after sickness and the resulting strain on the sutures

The injection is commenced with a fine needle a little beyond the lateral end of the proposed incision An intradermal wheal is produced at this point, a long needle introduced into the subcutaneous tissue, and about half an ounce of anæsthetic solution injected in this position The needle is then passed downwards and medially, and the subcutaneous fat infiltrated in the line of the incision The needle is then partly withdrawn and again advanced until it reaches the resistance of the aponeurosis of the external oblique This is gently pierced and about half an ounce of solution injected underneath so as to block the ilio hypogastric and ilio-inguinal nerves This may be all that is necessary As additional precautions the line of incision may be infiltrated intra dermally, and it is advisable to make a further injection around the neck of the sac after it is exposed The point of the needle should be inserted through the fascial coverings of the cord close to the abdominal inguinal ring and enough of the anæsthetic solution injected to distend the fascial coverings for some distance above and below the point of injection This procedure ensures a painless dissection of the sac

Femoral Hernia —A femoral hernia may be anæsthetised by infiltration along the line of the incision, or by injecting around the circumference of the hernia after the method of Hackenbruch After the sac has been exposed and defined, it is necessary to inject some novocaine solution around the neck, care being taken to avoid the femoral vein which lies on the lateral side

UMBILICAL HERNIA.—Local anæsthesia is sometimes of great value in dealing with umbilical hernia, especially if it is strangulated, in stout patients who are bad subjects for a general anæsthetic. The injection is best made around the circumference of the hernia. Several intradermal injections are made at points around the swelling, and through these the long needle can be introduced and the deeper tissues infiltrated. If the muscles are fairly well defined and can be felt, they may be infiltrated at the commencement, but it may be advisable in fat subjects to inject only the subcutaneous tissues to begin with, and to delay the injection of the muscles and extra peritoneal fat until the sac has been opened and a protecting finger can be introduced to guard the intestines. Omental adhesions can be divided without causing pain. If the intestines are extensively adherent to the sac it is better to infiltrate the points of adhesion, as extensive manipulation may cause cramp-like pains.

After the circumferential injection has been made in these cases it is best to wait for ten or fifteen minutes before making the incision in order to allow the anæsthetic solution to diffuse.

SUPRAPUBIC CYSTOTOMY.—In operations for drainage of the bladder local anæsthesia is highly successful. The skin and subcutaneous tissues are infiltrated in the line of the incision. The needle is then carried between or through the recti muscles and several drams injected into the layer of fat in front of the bladder. It is unnecessary to inject the wall of the bladder itself.

HÆMORRHOIDS.—In patients in whom there is some contra indication to the use of a general anæsthetic the removal of hæmorrhoids can be carried out quite safely

and painlessly under local anæsthesia A circumferential injection is first carried out round the muco cutaneous junction It is best to start the infiltration about an inch out from the anus as the skin immediately around the anal orifice is extremely sensitive The infiltration is made subcutaneously, and each re insertion of the needle is made just short of where the previous injection stopped When the circumferential injection has been completed, a finger is passed into the rectum, and the long needle introduced through the anæsthetised area, injecting as it advances, to a depth of about $2\frac{1}{2}$ inches, keeping just outside the sphincters Four such injections are made, one on each side of the bowel, one in front and one behind, from 5 to 10 c c being injected in each position

Anæsthesia results almost immediately and the anal canal can be readily dilated

THE TONGUE —For the Whitehead operation of re moval of one-half of the tongue, complete anæsthesia can be obtained by the infiltration method A long needle is introduced at the tip of the tongue and the injection carried in the middle line to a point behind the tumour The mucous membrane of the floor of the mouth and the glosso palatine fold are infiltrated, and a last injection made across the affected half of the tongue well behind the tumour

The tongue can be anæsthetised also by blocking the lingual nerve with a paraneural injection The nerve lies under the mucous membrane of the mouth opposite the last molar tooth If the tongue is drawn well over to the opposite side the nerve can be felt and the injection made around it The only drawback to this method is that it does not anæsthetise the posterior third, which is supplied by the glosso pharyngeal nerve

OPERATIONS ON THE SKULL AND BRAIN can be readily performed by infiltration of the scalp In the later stages of the recent war a large proportion of operations on the skull and brain were performed under local anæsthesia The brain itself is insensitive to touch and painful stimuli and infiltration of the scalp is all that is necessary A 1 per cent solution of novocaine with adrenalin has been commonly employed and is injected into the dense tissue of the scalp If it enters the loose areolar tissue between the scalp and the pericranium it is relatively ineffective (Dott) The advantages are that hæmorrhage is reduced to a minimum and the head can be conveniently and safely elevated and the intracranial tension thus reduced

## SPLANCHNIC ANALGESIA

This is a method of obtaining analgesia of the abdominal viscera by blocking their sensory nerve supply It has been shown by Langley that the sensory fibres from the viscera pursue an uninterrupted course upwards from their terminals in viscus or mesentery through the cœliac (solar) plexus upwards in the greater splanchnic nerve to the sympathetic trunk in the thorax through the white rami to the lower thoracic spinal nerves where they reach their nerve cells in the ganglia on the posterior nerve roots These sensory fibres resemble the peripheral sensory fibres in every respect they are medullated they are uninterrupted in their course from the sensory nerve ending to the nerve cell and their cells lie in the posterior root ganglia of the spinal nerves

The most convenient point for blocking the sensory nerve supply of the abdominal viscera is in the region of the cœliac plexus where the fibres are closely grouped together The plexus lies on the posterior abdominal

wall in relation to the abdominal aorta and behind the stomach at the level of the first lumbar vertebra It consists of three parts, the central plexus surrounds the origin of the cœliac artery and is connected on each side with the cœliac ganglion, a large, irregular structure lying on the corresponding crus of the diaphragm, overlapped by the suprarenal gland and on the right side by the inferior vena cava It lies in the retroperitoneal tissue and can be anæsthetised if a sufficient quantity of local anæsthetic solution is injected in the neighbourhood The retroperitoneal space at this level may be injected from the front after the abdomen has been opened, and this method has been widely used by certain Continental surgeons This procedure, however, involves manipulation of the viscera before they have been rendered analgesic, and this can probably not be done without causing the patient some discomfort The writer has employed only the posterior method

*Technique*.—The preliminary administration of narcotic drugs is advisable and is almost essential The patient has to endure several punctures of the skin and also of the periosteum of the first lumbar vertebra, the latter tissue in particular being highly sensitive The practice of the writer is to give $\frac{1}{4}$ gr of morphia and $\frac{1}{100}$ gr of hyoscine hypodermically one hour before operation, and $\frac{1}{6}$ gr of morphia and $\frac{1}{200}$ gr of hyoscine twenty minutes before This dosage usually has the effect of producing a state of "twilight sleep"

The needle employed resembles the one used for spinal anæsthesia, but is about 15 5 cm in length With the patient lying on the opposite side a wheal is raised with a fine needle at the lower border of the twelfth rib, 7 cm from the median plane, with novocaine solution (*see* Fig 62) Through this the long needle is introduced at an

angle of 45° with the median plane until it impinges on the body of the first lumbar vertebra It is then withdrawn almost to the skin and re introduced at a smaller angle until it is felt to glide tangentially along the side of the body of the vertebra This usually requires several

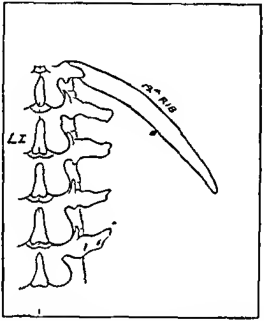



FIG 6 —The point at which the needle is introduced—at the lower border of the twelfth rib 7 cm from the median plane

attempts one feels one s way along the side of the vertebra until the needle is felt just to slide off (*see* Fig 63) The needle is pushed 1 cm further in and then lies in the retroperitoneal fatty tissue To make certain that a blood vessel has not been wounded the syringe is attached to the needle and suction is made If no blood appears 30 c c of 1 per cent novocaine is injected The patient

is then turned on the opposite side and the injection repeated. The patient is now placed on his back and the abdominal wall is injected along the line of the proposed incision with ½ per cent. novocaine in the manner already described

The mistake that is most likely to be made is to fail to

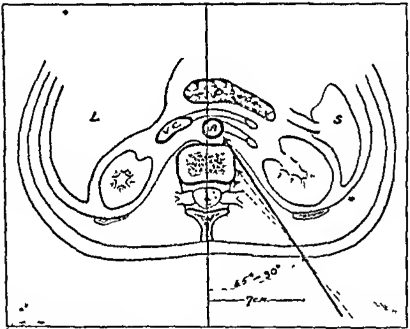



FIG. 63 —Transverse section at the level of the first lumbar vertebra, showing the region where the injection is made and the direction in which the needle is introduced

pass the needle to a sufficient depth A useful guide in determining whether the proper depth has been reached or not lies in estimating the degree of resistance to the piston of the syringe in making the injection; if the needle has reached the correct position, there is almost no resistance to the flow of the solution into the loose

retroperitoneal tissue whereas if the point of the needle is still embedded in muscle considerable resistance is felt in pushing the piston home The best indication as to the success of the anæsthesia lies in the condition of the muscular coat of the intestine If the cœliac plexus has been successfully blocked the sympathetic (dilator) impulses to the intestine are cut off and the intestine shows a tendency to become spasmodically contracted owing to the unopposed action of the vagus

This method of obtaining analgesia for abdominal operations is still on its trial It is claimed for it, in comparison with general anæsthesia that it diminishes shock by blocking the harmful afferent sensory nerve stimuli and that by obviating the use of a general anæsthetic it diminishes the risk of post-operative pulmonary complications and of post operative vomiting The writer has had a certain experience of the method, he is inclined to the belief that in a successful case the degree of shock is very much diminished In one case in particular a female on whom a partial gastrectomy was performed for carcinoma and in whom a cardiac breakdown had recently occurred the absence of shock was very striking

The principal drawbacks to the method are the expenditure of time required for the injections—about fifteen minutes—and the fact that considerable skill and experience are required to ensure a successful result The method* appears to be especially indicated in cases in which a severe operation such as a resection of stomach or bowel is to be performed in a patient who is a poor surgical risk

## ANALGESIA FROM THE APPLICATION OF COCAINE TO THE EYE OR TO A MUCOUS SURFACE

FOR OPERATIONS ON THE EYE —Analgesia is obtained by the instillation of a few drops of a 4 per cent solution

into the conjunctival sac This is repeated two or three times and analgesia is obtained in five or ten minutes It may be necessary to repeat the instillation during the course of the operation

FOR OPERATIONS ON THE NOSE PHARYNX OR LARYNX cocaine is commonly used A 5 or 10 per cent solution is employed and is merely painted on the surface Care must be taken that such strong solutions are not swallowed

## CHAPTER XXIV

# SPINAL ANÆSTHESIA

SPINAL ANÆSTHESIA or *Analgesia* consists in the production of analgesia in the lower extremities and in the lower part of the trunk by the injection into the subarachnoid space of an anæsthetic drug which blocks the spinal nerves as they enter and leave the spinal cord The cord ends at the lower border of the first lumbar vertebra and the subarachnoid space at the second sacral vertebra so that there is a considerable area into which the injection may be made without risk of injury to the cord It is in reality a special variety of regional analgesia the anæsthetic being injected into that part of the sub arachnoid space which is occupied by the cauda equina The subarachnoid space of the medulla spinalis contains the cerebro spinal fluid and communicates above with the subarachnoid space inside the skull and through the foramen of Magendie with the ventricular system of the brain The subdural space of the medulla spinalis is merely a capillary interval At the upper end of the *cauda equina* the nerve trunks of the two sides are separated by a median interval—containing only the filum terminale—which has been termed the cisterna terminalis It is into this median space that the injection is made in order to avoid wounding the nerve trunks and to procure equal diffusion of the anæsthetic to both sides of the middle line If the injection is made among the nerve trunks on one side a unilateral anæsthesia

may result, the drug being prevented from diffusing freely to the other side by the presence of the numerous nerves

The ligamentum denticulatum forms an imperfect scalloped septum between the posterior and the anterior nerve roots, passing from the surface of the cord to the dura mater The presence of this septum probably explains the fact that the motor nerves are not affected with the same constancy and to the same extent as the sensory roots

THE CEREBRO-SPINAL FLUID —The amount of this fluid between the sixth cervical vertebra and the lower end of the spinal canal is about 30 c c Its specific gravity varies between 1 004 and 1 010

## TECHNIQUE

The drugs which until recently were most commonly used for spinal anæsthesia were Novocaine, Stovaine, and Tropacocaine All of those, in order to develop a satisfactory analgesia require to be given in fairly concentrated solutions Those solutions have specific gravities higher than that of the cerebro spinal fluid They are therefore relatively heavy or hyperbaric This is a disadvantage if the operation is one which renders the Trendelenburg position desirable as the solution then tends to gravitate towards the upper part of the cord (*e g* the phrenic nerve roots at the level of the fourth cervical) Apart from the demands of the operation the Trendelenburg position is particularly desirable in spinal anæsthesia for its tendency to counteract the fall in blood pressure which occurs Various attempts to meet this difficulty have been made, and to render those heavy solutions light by mixing

alcohol with them In actual practice however when injected the light ingredient separates from the solution and rises in the cerebro spinal fluid leaving the solution of the drug also to follow the law of gravity and sink just as it normally does It is safer therefore when using solutions of those three drugs to regard them as hyperbaric and to guard against upward diffusion by gravity They are said to become fixed in about fifteen minutes from the time of injection after which the patient may be placed in the Trendelenburg position

*Dosage*—The dose of novocaine for spinal analgesia is up to 12 grm of stovaine and tropacocaine 07 grm They are made up with water or salt solution and various other ingredients are sometimes mixed *e g* alcohol adrenalin strychnine caffeine etc The solutions are obtainable in ampoules sterilised and ready for use Ampoules containing a maximum dose of novocaine crystals are also on the market to be dissolved in cerebro-spinal fluid withdrawn from the canal and this solution injected

The syringe and needle employed are illustrated in Fig 64

The point of the needle must be sharp but short If a needle with a long slender point is employed only part of the point may enter the membranes a free flow of cerebro spinal fluid may then take place but when the injection is made part of the anæsthetic solution escapes outside the membranes The needle should be $3\frac{1}{2}$ to 4 inches long and 1 mm in diameter A stylet fits inside the needle and prevents it from becoming blocked during the introduction To prevent the possibility of rusting both needle and stylet should consist of stainless steel The barrel of the syringe must consist of glass so that the appearance of the cerebro spinal fluid can be seen The

Record type is very satisfactory The syringe usually supplied for spinal analgesia has a capacity of 2 or 3 c c but one holding 10 c c is more useful Syringe and needle must be carefully sterilised by boiling in plain water, any trace of soda causes decomposition of the drug The ampoule containing the drug is sterilised in a strong antiseptic solution so as to avoid the possibility of

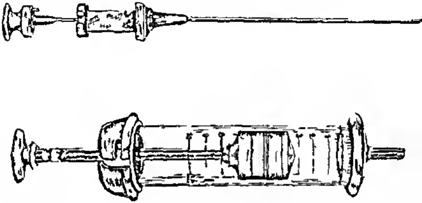


Fig 64—Needle and syringe for spinal analgesia Note the short *oblique character of the point of the needle The syringe is a* 10 c c Record

contamination of the hands when the drug is being transferred to the syringe

*Method of Injection*—The patient should be given a hypodermic injection of $\frac{1}{8}$ gr of morphine and $\frac{1}{150}$ gr of scopolamine an hour before the operation There are a number of minor variations in the method of making the spinal injection, but limitations of space forbid a discussion of theoretical questions and of the relative merits of the different procedures Only one method which has been found safe and reliable, will be considered here The injection is made in the space between the

third and *fourth lumbar spines the objective being the* mid line of the subarachnoid space between the two divisions of the cauda equina The position of the patient is such that the spaces between the lumbar spines are opened up as widely as possible The most convenient

FIG 65—Position for the injection The cross indicates the level at which the lumbar puncture is made—in the space between the third and fourth lumbar spines

plan is to have the patient sitting on the edge of the table with the head and shoulders bent well forward (*see* Fig 65) If the patient is unable to sit up the injection may be made with him lying on his side with the knees drawn up and the shoulders bent forward

*The skin of the back is carefully sterilised, painting*

with tincture of iodine serves admirably The ampoule containing the drug is opened, and the contents sucked into the syringe through a spare cannula The loaded

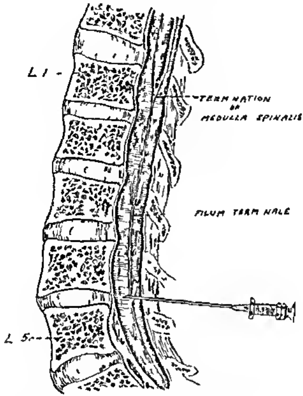



FIG 66—The needle has been passed in between the fourth and fifth lumbar spines The point lies in the centre of the subarachnoid space, well below the level of the spinal medulla

syringe is then placed on a sterile towel at the back of the patient With a little practice there is no difficulty in making the lumbar puncture The fourth lumbar spine is located by noting the level of the highest point on the

iliac crest—this may be indicated by an assistant A line joining the highest points on the two iliac crests will pass through the tip of the fourth lumbar spine When this process has been carefully identified the needle is introduced in the median plane midway between the third and fourth spine Some surgeons prefer to go in a little to one side of the median plane to avoid the resistance of the supraspinous and interspinous ligaments It is preferable however to make the puncture exactly in the middle line The resistance of the ligaments is not great and by this method there is a greater certainty of placing the injection accurately in the cisterna terminalis

The needle is passed forwards and very slightly upwards so as to hit off the centre of the subarachnoid space As the needle passes through the ligamentum flavum there is a sudden diminution of resistance and immediately afterwards the point of the needle lies in the subarachnoid space The passage of the needle through the membranes is sometimes accompanied by a slight pricking pain

The stylet is withdrawn at this stage and the cerebro spinal fluid usually trickles out drop by drop The syringe is picked up carefully emptied of air bubbles and fitted on to the needle The piston is withdrawn until the syringe is filled with cerebro-spinal fluid which mixes freely with the anæsthetic solution and the contents then slowly injected The 10 c c syringe is to be preferred for this purpose as it is essential to mix the drug thoroughly with the cerebro spinal fluid If the smaller syringe is used it should be refilled with cerebro-spinal fluid and emptied a second time so as to ensure thorough diffusion of the drug The needle is then withdrawn and the puncture sealed with collodion

The injection should never be made until a free flow

of cerebro spinal fluid is obtained, since this is the only certain indication that the needle has entered the sub-arachnoid space If failure is met with in the space between the third and fourth spines, the inter-spinous space above or below should be tried

After the injection has been completed the patient is placed flat on his back and then lowered into the Trendelenburg position Analgesia appears first in the scrotum and perineum, extends down the medial side of the leg to the foot, then appears on the front of the leg and travels up to the groin and the lower part of the abdomen The progress of the analgesia may be tested from time to time by lightly pinching or pricking the skin, the patient's eyes being screened When the analgesia reaches the level of the nipples, the patient is raised into the horizontal position and the operation may be commenced Some surgeons object to the lowering of the head as rendering paralysis of the respiratory centre from upward diffusion of the drug more likely If the drug is used within the limits of safe dosage, and the table elevated when the anæsthesia reaches the nipple line there seems to be little risk of this complication If analgesia is only desired in the lower extremity, the lowering of the table may be omitted, but if a good anæsthesia is desired above the level of the groin it should always be carried out

Analgesia is complete in five or ten minutes as a rule The duration varies from three quarters of an hour to an hour and a half If a preliminary hypodermic injection of morphine and scopolamine has been given, the patient lies quietly and patiently until the operation is completed In some cases the patient actually drops off to sleep from the effects of the morphine It is not uncommon to observe a temporary nausea and faintness about fifteen or twenty minutes after the injection has been made, and it is good

practice to give the patient a little brandy and water at this stage

## "LOW" SPINAL ANÆSTHESIA

Anæsthesia limited to the perineum and bladder is useful in many genito urinary and gynecological operations and may be obtained by using minimal doses of drug For this purpose 4 c c of a heavy solution of planocain (a novocaine preparation) is very satisfactory The technique described above should be followed, except that the patient should be kept sitting up after the injection for ten minutes, and thereafter should have the head and shoulders kept up With so small a dose of novocaine the fall in blood pressure is very slight

## COMPLICATIONS AND AFTER-EFFECTS

A great deal has been written in the past with regard to unpleasant results of spinal analgesia, but most of these would appear to have been the result of faulty technique or of the use of an impure or irritating drug When the anæsthetic is used in the manner described, the usual result is that, except for occasional nausea and faintness at the commencement, the patient has a comfortable, painless operation, and a recovery which is un marred by the sickness and other distressing symptoms which are so common after general anæsthesia The pallor and faintness which occasionally occur are probably due to the fall in blood pressure which usually takes place during spinal analgesia

*Deaths* have been recorded, and these have been ascribed to the drug having travelled too high and brought about paralysis of the respiratory centre in the medulla oblongata Too much importance has probably been ascribed to these fatal cases They have been most

common in patients greatly enfeebled by shock, old age, or debilitating illness, who are liable to die during the operation whatever anæsthetic is used Thousands of cases have been recorded without a death, and in the hands of surgeons of skill and judgment fatal cases are almost unknown

An occasional complication is severe *headache* which may persist for a week or longer Other complications are all exceedingly rare, paralysis of the lateral rectus muscle of the eyeball or of other ocular muscles has been recorded, and is probably due to toxic by-products which are the result of impurity of the drug Persistent nausea and paralysis of the bladder and rectum and even of the lower extremities have also been recorded but are to be regarded as the greatest rareties, and probably due to impurity of the anæsthetic

## PERCAINE IN SPINAL ANÆSTHESIA

With the discovery of the analgesic properties of percaine (hydrochloride of $\alpha$ butylcinchoninic acid diethylethylenediamide), a quinoline derivative quite distinct from the cocaine group, a definitely ' light ' or hypobaric solution became possible This is due to the potency of the drug rendering it effective in very dilute solution To Howard Jones we owe the development of this method the technique of which will be briefly outlined

The drug is put up in 20 c c ampoules containing percaine in a 1 in 1500 solution with 5 per cent sodium chloride The specific gravity of this fluid is 1 003, lower therefore, than that of the c s f The quantity of fluid to be injected depends on the level of anæsthesia desired For lower limb or perineal operations 6 to 8 c c , for lower abdominals (below the level of the umbilicus), 8 to 10 c c ,

and for higher abdominals, such as gall bladder or stomach operations, up to a maximum of 18 c c

Much of the technique already described for spinal anæsthesia is followed in using percaine The following special features demand mention A 20 c c syringe is necessary, and Jones recommends a fine needle He also recommends the avoidance of allowing more than a few drops of *c s f to escape.* The injection, which may be made at the third lumbar interspace, should be performed with the patient in the lateral position and *not* sitting up, with the object of limiting upward diffusion of the hypobaric solution After injection a hypodermic of ephedrine gr 1 or $1\frac{1}{2}$ should be given to counteract the fall of blood pressure which is associated with the injection of percaine, as with other spinal anæsthetics The patient should be immediately turned on to his face and kept in this position for ten minutes This ensures the contact of the drug with the posterior roots of the spinal nerves as they pass through the subarachnoid space Jones emphasises the importance of this position, neglect of which, he maintains, sometimes results in a perfect condition of muscular relaxation but an imperfect anæsthesia the anterior motor roots being acted upon but the posterior sensory roots, especially towards the upper limit of the solution's penetration, escaping Concurrently with the face down position the table is tilted into a slight Trendelenburg At the end of ten minutes the patient is turned on to his back, the slight Trendelenburg being maintained or, in operations demanding it, the complete Trendelenburg position adopted With this hypobaric solution no risk is associated with any degree of Trendelenburg position Care should be taken not to have any tilt in the opposite direction lest upward diffusion of the drug occur

Anæsthesia is usually complete in ten minutes and is of longer duration than with other spinal anæsthetics It may be relied on to last for two hours, and indeed very often lasts for three hours

By using a large quantity of percaine solution for upper abdominal operations, Jones aims at reaching the level of the fourth dorsal vertebra, so producing a splanchnic block It certainly seems to be more certain in its results than the various methods which have been employed in the attempt to ensure diffusion of the other spinal anæsthetics

*Percaine, while being subject to the ordinary sequelæ* associated with spinal anæsthesia, does not appear to produce them so frequently as do the other spinal anæsthetics

## INDICATIONS

Spinal analgesia may be used for any operation below the diaphragm Opinions vary considerably as to its place in upper abdominal surgery There are those who use it extensively on account of the perfect relaxation of the abdominal wall and the relative freedom from some of the unpleasant sequelæ of general anæsthesia On the other hand, the risk seems to be considerable, and the immunity from respiratory complaints which used to be claimed is very doubtful With a high spinal the action of intercostal muscles is interfered with, and this may be the explanation of the chest complications which frequently ensue It is of definite value, however, in operations below the umbilicus where bronchitis or other respiratory complication is to be feared In operations for intestinal obstruction where fæcal regurgitation is a symptom it obviates the very grave danger from inhalation of the fluid which a general anæsthesia presents In cases of diabetic gangrene it is useful *Low spinal block is a very*

safe method for perineal operations, cystoscopies, etc, and seems definitely superior to sacral analgesia in that it is easier to carry out and more certain in action

### CONTRA-INDICATIONS

Children up to the age of fourteen or so are apt to be frightened, and spinal analgesia is better avoided except in special cases It is contra indicated also in septic conditions on account of the possibility of septic meningitis resulting from metastasis of the infection, the drug having possibly the action of lowering the vitality of the cord and meninges In tuberculosis and syphilis it is better avoided for the same reason It should not be used where organic disease of the spinal cord or brain is already present

# APPENDICES

## APPENDIX I

### SOME EXPERIMENTAL OBSERVATIONS BY THE AUTHOR* UPON THE PHYSICAL FACTS OF ETHER EVAPORATION

The apparatus was very simple It consisted of a pump which would propel air towards the ether bottle, a glass bottle containing ether, the roof of which was pierced by two tubes, one of which carried the air from pump to bottle and the other from bottle to a Waller s tube, where it was collected The percentage of ether in the air was then estimated by Waller s gravimetric method The ether jar stood in a water bath which could be either left otherwise empty or filled up with water of known temperature The following tables show some of the results In each case, the air was propelled for five minutes by which time the cooling effect upon the ether was very marked, the figures given are averages taken from several observations

* J S R

[TABLE A

## TABLE A

### Air Blowing over Surface of Ether

| Temperature of Bath (Fahr.) before experiment. | Quantity of ether before experiment | Rate of Pump | Temperature of ether (Fahr.) at end of experiment | Per centage obtained |
|---|---|---|---|---|
| 75 | 100 c.c. | 30 | 50° F | 12.7 |
| 85 | 100 c.c. | 30 | 52° F | 12.8 |
| 75 | 100 c.c. | 90 | 45° F | 8.7 |
| 85 | 100 c.c. | 90 | 45° F | 8.8 |
| No water in bath | 100 c.c. | 30 | 32° F | 8.2 |
| No water in bath | 100 c.c. | 90 | 23° F. | 5.4 |
| No water in bath | 200 c.c. | 30 | 38° F | 9.6 |
| No water in bath | 200 c.c. | 90 | 29° F | 6.6 |

## TABLE B

Showing increased percentage obtained by "bubbling through" instead of "blowing over" ether—

### Water Bath at 75° F

| Quantity of ether | Rate of pump |
|---|---|
| 100 c.c. | 30 |

| | |
|---|---|
| Air blown over surface of ether gave percentage of ether . | 12.8 |
| Air bubbled *through* ether | 23.8 |

## TABLE C

Showing amounts of ether vaporised at varying pump rates In each case the temperature of the water bath was 75° and the initial amount of ether was 100 c c —

| Pump Rate | Amount of Ether Vaporised |
|---|---|
| 30 | 30 c c |
| 90 | 38 c c |

These experiments justify one in drawing the following conclusions —

(*a*) The addition of a water bath has a marked effect in increasing the strength of the vapour yielded, but small variations in the temperature of the bath (as between 75° and 85° F ) do not materially affect the issue

(*b*) If ether is vaporising quickly, it cannot pick up heat from the water bath as quickly as it is losing its own heat Though not shown in the tables, the actual loss of temperature on the water bath was small—about 2° F during the five minutes experiment

(*c*) The more forcible the blast of air blown over or through the ether, the less the percentage of ether yielded Table C shows that this loss of percentage is not compensated for by an increase in the total amount vaporised

Of course, these results only apply to the case of a strong current of air If the current of air were *very* small the ether could pick up heat as fast as it parted with it, and within moderate degrees a little increase of the air stream would increase the total amount of *ether vaporised without reducing the percentage* strength

These results are of some practical importance in connection with so-called "vapour anæsthesia" as given for instance by Shipway's instrument (page 136), and in devising and using the ether chambers of intratracheal apparatus.

## APPENDIX II

## THE PERCENTAGE STRENGTH IN OPEN ETHER

HEWITT and Syme (*Lancet* 27th Jan 1912) estimated the percentage of ether obtainable from an open mask with varying materials and quantities of the drug The results are tabulated below —

### *A* —A WHOLE MASK JUST MOIST

| Material stretched on mask | Number of layers | Percentage obtained |
|---|---|---|
| Gauze | 4 | 11 0 |
| | 8 | 11 4 |
| | 12 | 11 0 |
| Flannel | 1 | 8 0 |
| | 2 | 8 0 |
| Lint | 1 | 10 0 |

### *B* —WHOLE MASK WET

| Material stretched on mask | Number of layers | Percentage obtained |
|---|---|---|
| Gauze | 4 | 12 0 |
| | 8 | 13 4 |
| | 12 | 14 0 |
| Flannel | 1 | 8 0 |
| | 2 | 8 0 |
| Lint | 1 | 8 0 |

By excessive douching the observers were able to obtain 17 per cent

In these results, air and ether vapour were drawn by a pump through the material to imitate the inspiration, but no attempt seems to have been made to imitate expiration The effect upon the material used of moisture condensed from the expired air is not taken into account in these experiments This is a serious hiatus in the argument particularly as regards lint This material in actual use rapidly becomes quite sodden, and ether will not vaporise from it properly

In spite of this fault, these observations may probably be taken as quite reasonably accurate

With them may be compared the figures of Karl Connell, who working with quite accurate methods estimated the percentages of ether necessary to induce and maintain anæsthesia —

| Period of Anæsthesia. | Percentage |
|---|---|
| First 5 minutes (*i e* induction) | 18.0 |
| Next 25 | 14.0 |
| Next 30 | 12.0 |
| Next 60 | 12.5 |

Bad subjects on the average required an extra 4 per cent during first half hour, feeble patients required 2 per cent less (*Journal* of the American Medical Association 22nd March 1913)

## APPENDIX III

# THE ACTION OF ANÆSTHETICS UPON THE BLOOD

## THE BLOOD GASES IN ANÆSTHESIA

Buckmaster and Gardner (*Journal of Physiology*, vol xli page 246) analysed the blood gases in various stages of chloroform anæsthesia and some of their results are shown below in tabular form They show a very definite

| | Average volume in c c per 100 c c of blood | | | Average composition per cent of gas | | | *Relation of* $O_2$ *to* $CO_2$ |
|---|---|---|---|---|---|---|---|
| | $CO_2$ | $O_2$ | Nitr | $CO_2$ | $O_2$ | Nitr | |
| Normal cats | 25 07 | 13 60 | 1 00 | 63 [illegible] | 34 8 | 2 52 | 1 to 1 84 |
| Reflexes just reappearing | 29 02 | 11 49 | 1 33 | 65 06 | 25 44 | 2 87 | 1 to 2 55 |
| Reflexes just disappearing | 29 57 | 7 78 | 2 15 | 69 14 | 18 17 | 5·09 | 1 to 3 8 |
| 2nd Stage Anæsthesia | 36 00 | 8 14 | 1 49 | 71 27 | 16 12 | 2 95 | 1 to 4 32 |

reduction in the oxygen content of the blood So far as one gathers from the text of the paper the animals were not subjected to any considerable trauma during the progress of the anæsthesia so that the figures arrived

at with regard to the $CO_2$ content do not bear upon the acapnia question If there was no trauma, there would be no deep breathing, and a reduction of $CO_2$ could not be expected

Buckmaster returned later to this subject in a paper read before the Anæsthetic Section of the Royal Society of Medicine

By further research he is satisfied that there is a reduction of from 30 to 80 per cent in the ventilation of the lung quite early in chloroform anæsthesia, which of course corresponds with the increased $CO_2$ content of the blood He notes, however, that under ether there is practically the same reduction of lung ventilation, and increase of $CO_2$ but there is not the reduction of oxygen in the blood so strikingly shown in the case of chloroform He concludes that there is some special affinity between chloroform and the red blood corpuscles which results in a lowered oxygen content

### *Other Blood Changes in Anæsthesia*

Hamburger and Ewing (*Journal* of the American Medical Assoc, 1908) examined the blood changes incidental to surgical anæsthesia Their results may be condensed as follows —

*Nitrous Oxide* —Hæmoglobin is not permanently decreased and no anæmia follows the administration Hæmolysis is not increased The coagulation time of the blood is not always affected in the same direction Usually it is slightly increased

*Ether* —The hæmoglobin is slightly reduced and anæmia persists for seven to ten days Hæmolysis is not, however, materially increased There is some evidence of blood inspissation The coagulation time is markedly increased

*Chloroform* —The hæmoglobin is reduced and a distinct anæmia produced Hæmolysis is definitely increased There is a slight increase in the coagulation time

### *Acidosis in Anæsthesia*

It has already been stated (*see* page 14) that diminished alkalinity of the blood is no longer accepted as an explanation of surgical shock, but rather as a side effect of anoxæmia There would appear, however, to be some "acidosis" almost necessarily associated with anæsthesia

Carter in the archives of Internal Medicine, Chicago, September 1920, states that ether diminishes the alkali reserve even if respiratory exchange is artificially controlled and made uniform The greatest decrease is at the end of a long anæsthesia, it rapidly disappears in the recovery stage, reaching normal within two hours

Reimann dealt with the same subject at a meeting of the American Association of Anæsthetics in June 1919, his results being supported by another speaker, Wm de B MacNider The latter showed that if the lowering of alkalinity be allowed to go too far, the kidney ceased to function and became unresponsive to diuretics

The results of these and other workers give support to the practice referred to on page 59, of administering alkalies as a routine, for a day or two before operation under general anæsthesia, but the whole tone of Professor Maclean's paper, referred to on page 269, is to lay the emphasis upon the ketosis, and to reduce the importance of alkalies, while magnifying that of sugar both as a preventive and curative agent

Of considerable interest in this connection, though not actually referring to blood changes, is a con-

tribution by Rosenthal and Wesley Bourne on "The Effects of Anæsthetics on Liver Function" (*Current Researches in Anæsthesia and Analgesia*, Sept.-Oct. 1928). By means of a dye test which they employed any disturbance of liver function could be detected. The dye was injected intravenously into rabbits and dogs. Normally the liver removed it almost completely from the blood in fifteen minutes, but if the liver was injured it failed to take up the dye, which remained in the blood for long periods. Summarising their experiments with the various anæsthetics, they came to the following conclusions:—

(*a*) Brief periods of chloroform anæsthesia are sufficient to produce immediate and delayed toxic effects on the liver; half an hour of chloroform causes injury that requires eight days for functional recovery, while two hours of anæsthesia requires six weeks for return to normal.

(*b*) Ether produces a definite but transient impairment of function. Recovery is usually complete in twenty-four hours.

(*c*) Nitrous oxide and ethylene in presence of adequate oxygen supply do not produce any impairment of liver function, but in presence of marked asphyxia cause both immediate and delayed toxic action.

(*d*) Cyanosis in itself increases the toxicity of anæsthetics on the liver.

# INDEX

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